A Multisectoral Programming Model for India

Some Numerical Results

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This article is based on a study formulated as a detailed application of an inter-industry programming model for the Indian economy. The main objective of the study is to analyse the structure of imports and the scope for import-substitution in Indian industry within the context of the growth of the economy as a whole.

Here the author describes briefly the programming model and discusses selectively some of the more interesting numerical results.

[The study on which this article is based was carried out for the author's doctoral thesis "A Programming Model for Import Substitution in India", which was submitted to the Department of Economics, M I T, in June 1966. A more detailed description of the study is contained in a paper presented at the Sixth Indian Econometric Conference in Calcutta in December 1966, to be published in a forthcoming issue of "Sankhya".]

WITHIN the past decade a considerable variety of inter-industry programming models have appeared in the literature on economic growth and development.[1] These models have been concerned with the efficient allocation of resources between sectors—and sometimes over time—in the context of the planning of economic growth. Both because of the particularly pressing growth problems in the poor areas of the world, and because of a widespread belief that the market mechanism tends to be less effective in relatively undeveloped economies, many of the programming models in the literature have been formulated and tested with data from developing countries. India, in particular, has been favoured in this respect: a long-standing commitment to economic planning, as well as a relatively plentiful supply of statistical data, have made it especially attractive for model-builders.

Many of the programming models to date have been presented in "demonstration" or "pilot" studies, where the attention is focussed more on the theoretical formulation of computable models than on their numerical implementation. The models applied to India have shared this emphasis on technique as opposed to empirical detail. Numerical applications have been carried out on the basis of a relatively aggregated interindustry description of the economy, so that the results emerge in terms of broad sectoral aggregates and macroeconomic magnitudes.[2] While such studies and their results are undoubtedly of interest, there are a number of respects in which a more detailed quantitative analysis can yield significant dividends.

In the first place, it is useful to set up interindustry planning models on the basis of sectors or industries in terms of which the actual plans are formulated. Models which prescribe targets for the engineering sector as a whole are of little use to a planner who is interested in the future demand for railway wagons or diesel engines. Secondly, a detailed empirical study can adjust to the differing quality of statistical information available for different sectors of the economy. Depending on the availability and/or suitability of the data, some sectors can usefully be treated in great empirical detail within the inter-industry framework of a model, while others are best aggregated or made explicitly subject to exogenous assumptions. Finally, one of the crucial problems in the strategy of economic growth concerns the pattern of industrialisation and foreign trade. Many programming models involve a degree of sectoral choice between domestic production, imports and/or exports. If such choice elements are to be meaningfully approached in the context of a programming model, it is essential that the relevant sectors be defined in fairly precise terms rather than in broad aggregates.

With these considerations in mind, the study upon which this article is based was formulated as a detailed empirical application of an inter-industry programming model to the Indian economy. The main objective of the study was to analyse the structure of imports and the scope for import substitution in Indian industry, within the context of the growth of the economy as a whole.

II

A Brief Description of the Model

The programming model is based on a highly disaggregated description of the Indian economy—involving some 147 endogenous sectors as listed in Table 1 (p 764)—but pays for the resulting costs of computation by being limited to a single period of time. All of the numerical magnitudes of the model relate to the target year 1975, which is compared to the base year 1965. The inter-industry detail is confined to the endogenous industrial part of the economy which forms the focus of the analysis, and in which the choice mechanism of the model is explicity operative. The remaining parts of the economy—primarily the agricultural and service sectors—are treated exogenously. They enter the model only insofar as they affect the demand for industrial sector products, and as they are needed to compute the overall trade and expenditure aggregates.

The model is programmed specifically to generate alternative patterns of domestic production and imports which satisfy a set of predetermined goals of final demand in

Table I

Code	Sector
100	**Mineral Industries**
111	Iron ore
112	Manganese ore
113	Chromite
114	Bauxite
115	Copper ore
116	Lead concentrate
117	Zinc concentrate
118	Ilmenite
119	Other metallic minerals
120	Gold
131	Limestone
132	Dolomite
133	China Clay
134	Gypsum
135	Salt
136	Mica
137	Other nonmetallic minerals
141	Rock phosphates
142	Sulphur
143	Asbestos
144	Cryolite and fluorspar
150	Minor minerals
160	Crude oil
200	**Fuel and Power Industries**
210	Coal
220	Coke
230	Electricity
241	Light distillates
242	Kerosenes
243	Diesel oils
244	Fuel oils
245	Bitumens
246	Other petroleum products
250	Lubricating oils
300	**Light Industries**
311	Sugar
312	Tea
313	Vegetable oils
314	Hydrogenated oils
315	Other food, beverages and tobacco
320	Jute textiles
332	Woolen textiles
333	Art silk fabrics
334	Other textile manufactures
340	Leather and products
350	Rubber products
361	Wood products
362	Glass
363	Refractories
364	Other nonmetallic mineral products
370	Cement
381	Paper and paperboard
382	Newsprint
400	**Chemical Industries**
411	Nitrogenous fertilizers
412	Phosphatic fertilizers
413	Potassic fertilizers
421	Sulphuric acid
422	Soda ash
423	Caustic soda
424	Other inorganic chemicals
430	Organic chemicals
441	Dyestuffs
442	Plastics and synthetic resins
443	Synthetic rubber
444	Synthetic fibres
445	Chemical pulp
446	Soaps
450	Paints
460	Drugs and pharmaceuticals
470	Other chemicals and products
500	**Metallurgical Industries**
510	Pig iron
521	Finished steel
531	Ferro-manganese
532	Ferro-silicon
533	Other ferro-alloys
541	Aluminum
542	Copper
543	Lead
544	Zinc
545	Tin
546	Nickel
547	Other base metals
551	Cast iron pipes
552	Steel pipes and tubes
553	Iron castings
554	Steel castings and forgings
555	Heavy ferrous structurals
560	Light metal fabrication
600	**Mechanical Engineering**
611	Machine tools
612	Boilers
613	Diesel engines
614	Pumps
615	Compressors
616	Refrigeration equipment
617	Material handling equipment
618	Conveying and hoisting machinery
621	Construction machinery
622	Mining machinery
623	Drilling machinery
624	Agricultural machinery
631	Textile machinery
632	Jute mill machinery
633	Sugar machinery
634	Tea processing machinery
635	Paper mill machinery
636	Cement machinery
637	Chemical equipment
640	Ball bearings
650	Instruments
661	Sowing machines
662	Typewriters
663	Watches and clocks
670	Other mechanical engineering products
700	**Electrical Engineering Industries**
711	Thermal turbo-generators
712	Hydro turbo-generators
713	Electric motors
714	Transformers
715	Switchgear and control-gear
720	Cables, wires and flexes
731	Refrigerators
732	Air conditioners
733	Electric fans
735	Electric lamps
736	Dry cells
737	Storage batteries
738	House service meters
739	Radio receivers
740	Communications equipment
750	Other electrical engineering products
800	**Transport Equipment Industries**
811	Steam locomotives
812	Diesel locomotives
813	Electric locomotives
821	Railway wagons
822	Railway coaching stock
831	Automobiles
832	Commercial vechicles
833	Motorcycles and scooters
840	Bicycles
850	Other transport equipment
900	**Transport Services**
910	Rail goods transport
920	Rail passenger transport
930	Road goods transport
940	Road passenger transport
951	Automobile transport
952	Motorcycle and scooter transport
953	Bicycle transport

the target year 1975. It differs from a straightforward consistent requirements planning model in that it allows explicitly for choice between production and importing activities, according to comparative cost criteria in a linear programming framework. The operation of the model begins logically with the setting of a goal for total consumption in the target year. This aggregate goal is determined by projecting forward from the base year a desired annual rate of growth of consumption. Using (per capita) expenditure elasticities, and comparing with the base year consumption pattern, the consumption of industrial goods is first separated from the target year level of total consumption and subsequently broken down into a vector of consumption demands for the products of the disaggregated sectors' endogeneous to the interindustry framework of the model.

In contrast to the treatment of importing activities as explicit choice elements in the model, estimates of exports are specified exogenously on the basis of independent projections for the target year 1975. This asymmetry in the approach to foreign trade does not imply that export promotion is in any way less important than import substitution, but it reflects the more complicated nature of optimal choice among exporting activities. Unless both the internal supply of, and the external demand for, each sectoral type of export can be regarded as perfectly elastic at a given price, the treatment of exporting activities as choice elements in the model would call for an explicitly non-linear formulation. Apart from some additional costs of computation, such an approach would require a much greater base of quantitative information on export possibilities in the target year 1975 than could be obtained or used in the study[4]. In the absence of the data which would permit a realistic non-linear formation, it would appear just as meaningful to study the effect of alternative export possibilities by parametric variation of exogenously given export levels than by allowing for an arbitrary range of choice exporting activities according to linear comparative cost criteria.

The total demand for the output of each endogenous sector includes the pre-determined consumption and export demands plus the demands for use as current and capital inputs. The latter arise both from the endogenous sectors and from the various exogenous parts of the economy. For each exogenous source of demand, a set of current and capital input demand vectors must be projected to the target year and specified exegonously. The corresponding demands from the endegenous sectors are derived from the interindustry structure of the model. Current input demand in the target year is related via current flow coefficients to the corresponding output levels of the domestic production activities. Capital input demand in the target year is related via current flow coefficients to the corresponding output levels of the domestic production activities. Capital input demand in the target year is related via incremental capital coefficients and a stock-flow conversion factor to the required increases in capital stock between the base year and the target year[5]. These increases in capital stock are in turn related to the corresponding increases in domestic production levels via a set of incremental capital-output ratios.

The demand for endegonous sector output in 1975, over and above that which can be supplied from capacity installed prior to 1965, can be met in general either from increased domestic productive capacity or from imports. The model includes activities for increasing domestic capacity and/or for importing, in all sectors where one or both are economically feasible. The domestic production activities require, in addition to inputs of other endegenous sector products on current and on capital account, inputs of domestic and foreign primary factors. The domestic primary factors include both labour and exogenous sector inputs, which are measured and aggregated according to their rupee cost. The foreign primary factor is simply foreign exchange, which is required in the form of non-competitive import inputs for the domestic production activities. These activities thus entail—directly and indirectly—both domestic resources costs and foreign exchange costs. The importing activities—on-the-other-hand involve only foreign exchange costs.

Capital is treated in the model not as a primary factor, but as a flow of (intermediate) services provided by the capital stock associated with each productive activity. The cost of these services in the target year is accounted for by applying an exogenously determined percentage rate of gross capital consumption to the endogenously evaluated cost of each stock of capital equipment. This capital charge includes both interest and depreciation, and can be varied parametrically according to different estimates of the appropriate figure. In the programming-runs described in this paper, it was uniformly set equal to 18 per cent.

The model is programmed to solve for a pattern of production and imports in the target year 1975 which minimizes a cost function made up of a weighted sum of domestic and foreign primary factor costs, measured respectively in rupees and dollars. By varying these weights — i e, by altering the rate of exchange between rupees and foreign currency — a set of solutions can be generated which satisfy the predetermined final demand goals with (inversely) varying requirements of internal and external resources.

III

A Summary of the Results

The model described in the previous section was programmed under a variety of parametric assumptions to provide a wide spectrum of alternative (optimal) solutions. The key parameters include the following: (1) the rate of growth of exports from 1965 to 1975; (2) the anticipated levels of a subset of non-competitive import coefficients which might reasonably be expected to decline by 1975; (3) the targetted rate of growth of aggregate consumption from 1965 to 1975; and (4) the relative weight given to domestic and foreign costs in the objective function to be minimized.

Table 2 displays some of the alternative values assigned to these key parameters. The various cases can be divided into three groups according to the basic assumptions made about exports and non-competitive imports. In the first group, the rate of growth of exports was set equal to 5 per cent per year, with an appropriate sectorwise breakdown, and the values of the relevant non-competitive import coefficients (applying mainly to machinery and parts imports) were assumed to fall to one half of their levels during the Third Plan period. In the second group, the rate of growth of exports was raised to 7 per cent per year; and in the third group, the non-competitive import coefficients were lowered to one third of their Third Plan levels.

In each group of cases, the targetted annual rate of growth of aggregate consumption between 1965 and 1975 was fixed successively at 7.5 per cent, 6.0 per cent and 4.5 per cent, respectively. From the corresponding aggregate consumption levels in 1975, related sets of values were derived for the final consumption demand, and also for the associated exogenous sector demands on both current and capital account, for the output of each individual sector. Finally, alternative solutions were generated in every case by varying the ratio of weights on foreign and domestic costs in the minimand from 4.75 to infinity. Each weight ratio corresponds to an effective rate of exchange between rupees and dollars. When the ratio is equal to 4.75, it is assumed that the official pre-devaluation exchange rate measures the relative scarcity of foreign exchange. As the ratio is raised above the initial level, a premium is placed upon foreign exchange, and when the ratio becomes infinite, foreign exchange costs alone enter into the minimand.

Table 2: Identification of Alternative Cases

	Rate of Growth of Consumption (Per cent)	Rate of Growth of Exports (Per Cent)	Non-Competitive Import Coefficients*
A-1	7.5	5.0	1/2
A-2	6.0	5.0	1/2
A-3	4.5	5.0	1/2
B-1	7.5	7.0	1/2
B-2	6.0	7.0	1/2
B-3	4.5	7.0	1/2
C-1	7.5	5.0	1/3
C-2	6.0	5.0	1/3
C-3	4.5	5.0	1/3

* 1975 values as compared with 1960-65 values, for subset of non-competitive imports.

Table 3: Import Substitution by Sector

Sl No	Code No	Sector
1	738	House service meters
2	611	Machine tools
3	662	Typewriters
4	624	Agricultural machinery
5	612	Boilers
6	613	Diesel Engines
7	733	Water coolers
8	160	Crude oil
9	622	Mining machinery
10	522	Special steel
11	614	Pumps
12	637	Chemicals equipments
13	821	Railway wagons
14	623	Drilling machinery
15	712	Hydro-turbo-generators
16	732	Air conditioners
17	731	Refrigerators
18	711	Thermal Turbo-generators
19	544	Zinc
20	542	Copper
21	532	Ferro-silicon
22	541	Aluminium
23	422	Soda ash
24	822	Railway coaching stock
25	543	Lead
26	623	Mtorocycles and scooters
27	421	Sulphuric acid
28	445	Chemical pulp
29	423	Caustic soda
30	813	Electric locomotives
31	812	Diesel locomotives
32	640	Ball bearings

Sectoral Results

The solution to each programming run can be described in terms of both the primal and the dual variables of the linear programming problem. The primal variables are the basic choice activities of the model: the (incremental) domestic production activities, and the alternative importing activities. The dual variables are the shadow prices associated with each of the constraints of the system. These shadow prices are expressed in terms of the minimand; thus the shadow price of each sectoral commodity denotes the cost of that commodity in terms of the given weighted combination of primary factor costs.

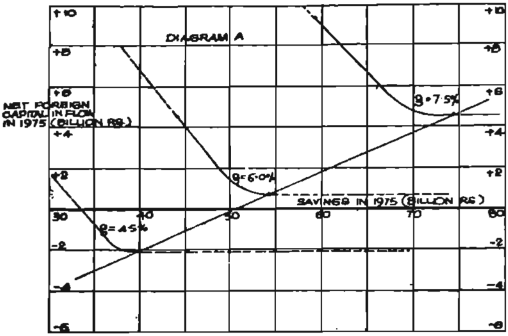
A similar qualitative pattern of choice characterised each set of solutions under the various assumptions considered. In the solutions for which the weight ratio was set equal to 4.75, there were — in addition to essential non-competitive imports — also competitive imports in approximately 30 of the endogenous sectors. These sectors consisted mainly of modern engineering industries, but included also some base metals and heavy chemicals. they are listed in Table 3.[6] For the remaining hundred-odd producing sectors — of which about 30 faced competitive imports — domestic production was cheaper than importing at the pre-devaluation exchange rate, and was hence preferred for every run of the model. As the weight ratio was raised to reflect an increasing premium on foreign exchange, there was a progressive substitution of domestic production activities for competitive imports. The sectors involved are listed in Table 3 in the order in which the substitution took place under the initial set of basic assumptions. This ordering was relatively insensitive to the alternative assumptions. Finally, in all of the polar solutions for which foreign exchange costs alone were minimized, the model predictably replaced all competitive imports with domestic production activities and thereby reduced the import bill to the minimum of essential non-competitive imports[7].

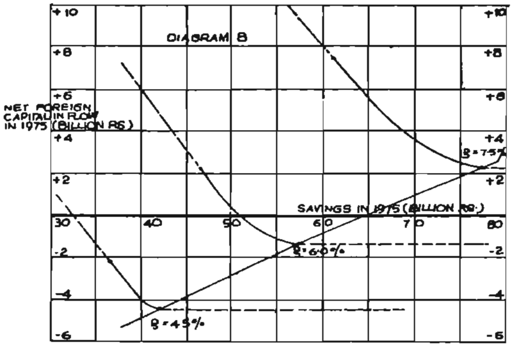
In the solutions obtained by minimizing foreign exchange costs alone, the shadow prices for each sectoral distribution constraint reflect simply the (minimal) foreign exchange content of a unit of output from the corresponding domestic production activity. For each sector the ratio of the shadow price to the alternative import price then represents the relative foreign exchange content of domestic production vis-a-vis importing activities. The higher this ratio, the lower the net saving of foreign exchange afforded by import substitution. In table 4, 41 endogenous production activities[8] are listed in the order of their relative foreign exchange content in 1975, as calculated from the shadow prices of an import-minimizing solution under the initial set of basic assumptions. There is naturally a fairly close correspondence between the rank orderings in Tables 3 and 4: sectors near the top of Table 4 are found close to the bottom of Table 3. The sequential order of import substitution presented in Table 3 depends both on the relative foreign exchange contents shown in Table 4 and on the total domestic resource content of each production activity. Sectoral differences in the latter account for the differences in the ordering of the two tables: the higher the rupee content of a domestic production activity, the later it will substitute for imports as the premium on foreign exchange is increased.

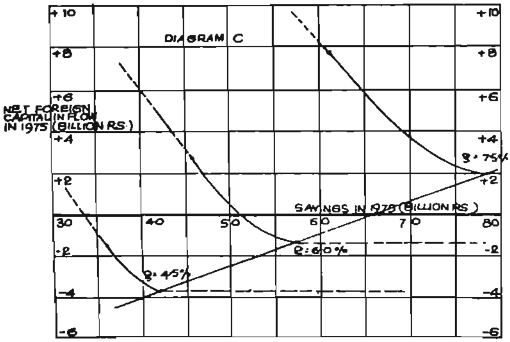
The primal solution to each of the programming runs includes incremental output figures for 136 endogenous production activities, as well as import levels for all of the sectors which admit of imports. Because of the vast amount of data involved, these figures will not be tabulated here; instead, the primal results will be summarised in terms of their macro-economic implications. Since the scope of the model is limited to the industrial part of the Indian economy, it was necessary to supplement each solution with estimates of exogenous magnitudes

Table 4: Relative Foreign Exchange Content of Domestic Production Activities

Serial No.	Code	Activity	Cases A B	Case C
1	640	Ball Bearings	95.8%	81.4%
2	812	Diesel locomotives	84.8	72.2
3	421	Sulphuric Acid	81.8	77.7
4	423	Caustic Soda	79.1	68.9
5	445	Chemical pulp	78.7	64.1
6.	813	Electric locomotives	72.8	63.4
7	833	Motorcycles and scooters	58.6	50.6
8	711	Thermal turbo-generators	53.0	44.6
9	541	Aluminum	52.6	45.7
10	712	Hydro-turbo-generators	52.0	44.6
11	532	Ferro-silicon	49.9	43.5
12	443	Synthetic rubber	47.1	38.3
13	822	Railway coaching stock	46.5	40.1
14	522	Special steel	46.1	43 1
15	623	Drilling machinery	46.0	39.2
16	613	Diesel engines	45.6	41.5
17	422	Soda ash	44.3	38.2
18	732	Air conditioners	42.9	37.9
19	731	Refrigerators	42.9	37.8
20	637	Chemical equipment	42.9	37.8
21	714	Transformers	41.3	38.5
22	424	Other nonorganic chemicals	41.1	35.9
23	614	Pumps	40.8	35.7
24	412	Phosphatic fertilizers	39.5	37.9
25	622	Mining machinery	39.5	33.2
26	442	Plastics	39.4	32.3
27	137	Other nonmetallic minerals	38.2	32.1
28	670	Other mech engineering	36.3	30.6
29	444	Synthetic fibres	36.3	30.6
30	750	Other elec engineering	33.6	30.6
31	612	Boilers	33.5	28.5
32	430	Organic chemicals	33.3	28.5
33	611	Mechine tools	33.2	28.2
34	821	Railway wagons	32.9	28.9
35	662	Typewriters	32.5	27 7
36	733	Water coolers	32.1	27.8
37	617	Material handling equipment	31.6	26.8
38	720	Cables, wires and flexes	31.4	26.9
39	382	Newsprint	31.4	26.9
40	624	Agricultural machinery	31.3	27.3
41	832	Commercial vehicles	30.8	26.7







in 1975 in order to complete the economy-wide picture

Macro-Economic Results

The macroeconomic results of the programming runs can be illustrated in terms of the internal resources — measured by gross domestic savings in 1975 — and the external resources — measured by the net inflow of foreign capital[9] in 1975 — required to sustain given targetted rates of growth of aggregate consumption. Diagrams A, B and C present the results obtained under the alternative sets of basic assumptions A, B and C. To make the figures more readily comparable, both savings and foreign capital inflow are shown in billions of rupees at 1960 prices, with foreign exchange converted at the then prevailing official exchange rate.

For each of the nine cases of Table 2, the set of alternative required combinations of internal and external resources is drawn on the appropriate diagram as a continuous contour.[10] For each group of basic assumptions, the three contours corresponding to the three different consumption targets can be interpreted as isoquants of an aggregative function relating the rate of growth of consumption to the inputs of savings and foreign capital. Additional isoquants of the same kind could be interpolated to represent different consumption targets. The left hand end of the continuous part of each contour corresponds to the solution in which the weight ratio in the minimand conforms to the official pre-devaluation rate, while the right-hand end corresponds to the solution in which all the weight is placed on foreign exchange. The contours could also be extended further to the left (as indicated by the broken lines), where they would correspond to solutions based on weight ratios giving even greater emphasis to domestic vis-a-vis foreign costs.

Read from left to right, the isoquants of Diagrams A, B and C reflect the substitution of domestic production activities for competitive imports that takes place as the premium on foreign exchange is raised. The marginal rate of substitution between savings and foreign capital inflow — given by the slope of the isoquants — shows considerable invariance under the alternative assumptions considered. Up to an effective exchange rate of about twice the official pre-devaluation rate, the isoquants are almost straight lines and are also reasonably parallel as between cases. Thus for a wide range of combinations there is a more or less constant trade-off between domestic and foreign effort which equates 1 rupee of net foreign capital inflow with roughly two rupees of gross domestic savings.

The marginal rate of substitution between savings and foreign exchange increases rapidly as the foreign exchange minimizing solution is approached at the right hand end of each contour. This point defines the limit beyond which savings alone are of no avail in raising consumption possibilities. Further to the right, there is no more scope for import substitution, and the isoquants become straight lines parallel to the savings axis at a level representing the minimum net inflow of foreign capital required to sustain the given targetted rate of growth of consumption.

For each group of basic assumptions, a cut-off line joining the right-hand ends of the three different consumption isoquants divides the range of values where there are substitution possibilities (to the left) from the range of values where there is no further scope for import substitution (to the right). Each cut-off line can be used to determine the maximum amount of saving that can be translated into productive investment, and hence also the maximum sustainable rate of consumption, corresponding to any given net inflow of foreign capital. Conversely, the cut-off line can be used to evaluate the minimum level of net foreign capital inflow consistent with any given rate of growth of consumption.

Under the initial set of basic assumptions, the maximum rate of growth of consumption that can be sustained without any net capital inflow appears from Diagram A to be approximately 5.5 per cent per year. This would call for gross savings of about 50 billion rupees in 1975, representing an average rate of saving of 15 per cent in 1975, and an implied marginal rate of saving between 1965 and 1975 of close to 19 per cent. To achieve a targetted rate of growth of consumption of 7.5 per cent per year, the minimum net capital inflow in 1975 would appear to be between 4 and 5 billion rupees. This in turn would require gross savings of close to 75 billion rupees in 1975, which implies an average rate of 18½ per cent and a marginal rate of 23½ per cent. Alternative strategies with less emphasis on import substitution would allow the same consumption targets to be achieved with lower rates of saving and higher levels of foreign capital inflow.

As compared with the initial set of assumptions, it will be observed from the diagrams that the more optimistic export projections of group B, or the lower values for non-competitive import co-efficients of group C, have the effect of displacing the isoquants downward. Thus they allow the same consumption targets to be satisfied with less savings and/or less foreign capital inflow, and they allow higher consumption levels to be attained with any given combination of internal and external resources. Furthermore, the isoquants — and hence the cut-off lines — in Diagrams B and C are also shifted to the right, relative to their position in Diagram A. This means that a greater amount of savings can be translated into productive investment for any given level of net foreign capital inflow.

At a zero trade deficit, either the higher export projections or the lower non-competitive import coefficients allow for a maximum (productive) level of gross savings in 1975 of approximately 65 billion rupees, which in turn will sustain a maximum rate of growth of consumption of the order of 6.5 per cent. As compared with the initial results, the more optimistic assumptions thus permit an increase of 1 per cent in the rate of growth of consumption without any additional foreign capital inflow. The corresponding average and marginal savings rates are 18 per cent and 23 per cent, respectively, representing increases of 3 per cent and 4 per cent over the requirements of the initial case.

IV

Conclusion

It may be useful, in conclusion, to compare the qualitative nature of the macroeconomic results that emerge from the multisectoral model of this study, with the results obtained from aggregate models of a similar kind. Chenery and Bruno[11], McKinnon[12], and Chenery and Strout[13] have worked with aggregate models emphasizing the two independent constraints on growth imposed by savings, on the one hand, and foreign exchange, on the other. The savings constraint is a familiar one: assuming a constant incremental capital-output ratio, the rate of growth of an economy is limited by the rate of investment, which is equal to the sum of domestic savings and foreign savings (net capital inflow).

The phenomenon of an independent foreign exchange constraint has been more recently stressed in connection with the industrialisation of underdeveloped economies[14]. When exports are limited exogenously (e g by stagnant world demand), and when noncompetitive imports are required in fixed proportions for domestic production and/or investment, there is always a point beyond which potential domestic savings cannot be put to use, and the growth of domestic output cannot be increased, for lack of foreign exchange to purchase specific complementary imports. At this point, a higher growth rate can be attained only by working directly on the foreign exchange constraint — by increasing exports, reducing noncompetitive imports, or receiving additional foreign aid (net capital inflow).

The implications of a simple aggregative model embodying these two constraints could also be portrayed in the form of the graphs in the three diagrams. With a single aggregate capital output ratio, and a single aggregate ratio of imports to total output[15], the result would be consumption isoquants consisting of two straight lines meeting at a cut-off line of the same kind as shown in the diagrams. To the right of the cut-off line, the isoquants would be parallel to the savings axis, reflecting the fact that the foreign exchange constraint was binding and additional savings alone were of no use in raising consumption possibilities. To the left, the isoquants would be straight, parallel lines, reflecting the constant trade-off between savings and foreign capital inflow that prevails when the savings constraint is binding. Since, under these circumstances, foreign capital inflow plays only the role of foreign savings, the slope of the lines would be 45 degrees in the case of output isoquants. In the case of the consumption isoquants of the diagrams, the slope of the line would be less than 45 degrees because, unlike domestic savings, foreign savings adds to the total supply of savings without subtracting from total consumption.

By contrast with the results of an aggregative model, the results of the multisectoral model of this study — involving a wide range of substitution possibilities between domestic production and imports — show a relatively smooth approach to the foreign exchange bottleneck. There is still, to be sure, a cut-off line beyond which no further possibilities for substitution arise; however, this cut-off line is reached only after all possibilities for import substitution have been exhausted. In the process, the overall import-output ratio in the economy gets depressed to a minimum level well below its base year value, and the overall capital output ratio rises above what it would have been with less import substitution. Thus the rigid implications of the aggregative madel are tempered by the introduction of choice among linear activities at the sectoral level.

The element of choice in the programming model is brought into play by variation of the effective rate of exchange between the rupee and the dollar. The resulting re-allocation of domestic and foreign resources is reflected by changes in the values of the aggregate capital output and import-output ratios. Table 5 presents the alternative values[16] for these ratios implied by alternative solutions to the programming model. A, B and C represent as before the three sets of basic assumptions about exports and non-competitive imports; g denotes the targetted rate of growth of consumption; and Θ is the effective rate of exchange (the rupee price of the dollar). It is clear from the table that the values of the two ratios vary not only with Θ, but also significantly with g and — in the case of the import ratio — with the alternative assumptions A, B and C.

The multisectoral linear programming model of this study provides a more flexible — and hence also a more realistic — reprerentation of the economy than any simple aggregative, or less disaggregated, model could. In at least two important respects, however, a greater degree of realism could be achieved by widening the scope for choice in the model. First sectoral export levels — as well as competitive imports — could be made a function of the effective rate of exchange[17]. Secondly, the sectoral composition of consumption — which was fixed (at the margin) for the present exercise — could also be allowed to adjust to some extent to the relative scarcity of domestic and foreign resources[18].

Each of these extensions would have the effect of allowing for even greater flexibility in the model; for any given variation in the effective rate of exchange, an even greater degree of re-allocation of resources

Table 5: Aggregate Coefficients

		Incremental Capital-Output Ratio 1965-1975			Import-Output Ratio 1975*		
g	O	A	B	C	A	B	C
7.5%	4.75	2.03	2.03	2.04	5.32	5.95	5.34
	6.00	2.07	2.07	2.10	5.29	5.39	4.62
	7.50	2.12	2.11	2.13	4.87	4.94	4.27
	10.00	2.13	2.12	2.15	4.78	4.86	4.14
	15.00	2.18	2.18	2.21	4.51	4.57	3.85
	-	2.25	2.26	2.28	4.41	4.46	3.73
6.0%	4.75	2.19	2.18	2.19	5.34	5.49	4.87
	6.00	2.23	2.22	2.24	4.82	4.94	4.25
	7.50	2.26	2.26	2.27	4.50	4.62	3.96
	10.00	2.27	2.27	2.29	4.44	4.56	3.90
	15.00	2.32	2.32	2.35	4.23	4.32	3.61
	-	2.39	2.39	2.41	4.13	4.25	3.52
4.5%	4.75	2.50	2.47	2.49	4.67	4.82	4.18
	6.00	2.53	2.51	2.54	4.23	4.34	3.70
	7.50	2.54	2.52	2.55	4.19	4.30	3.67
	10.00	2.56	2.53	2.56	4.08	4.27	3.56
	15.00	2.59	2.58	2.62	3.96	4.07	3.37
	-	2.66	2.64	2.67	3.89	3.97	3.28

* 1965 value = 7.66

would be called for. The increased possibilities of substitution would further weaken the rigid conclusions of the simplest aggregative model, and push somewhat further back the spectre of a foreign exchange bottleneck. Whether this spectre can — in the Indian case — actually be wholly exercised would depend on the extent to which export levels and consumption patterns are, or can be made, responsive to price changes. My own feeling — based as much on subjective judgment as on the numbers I have generated here — is that a foreign exchange bottleneck is still very much a factor to be reckoned with in the context of India's development plans[19].

Footnotes

1 See, for example, H B Chenery and K S Kretschmer, "Resource Allocation for Economic Development", "Econometrica" (October 1956); J Sandee, "A Demonstration Planning Model for India", Statistical Publishing Society, Calcutta (1960); S Chakravarty and L Lefeber, "An Optimizing Planning Model", "The Economic Weekly", Annual Number (February 1965); M Bruno, "A Programmings Model for Isreal" and A S Manne, "Key Sectors of the Maxican Economy, 1962-1972", in I. Adelman and E Thorbecks (eds), "The Theory and Design of Economic Development", Johns Hopkins Press, Baltimore (1966).

2 Two linear programming models have been applied to the Indian economy; Sandee's "demonstration" planning model involved 13 sectors (see J Sandee, op cit), and the optimizing model developed by Chakravarty, Eckaus and Lefeber distinguished 11 sectors (see S Chakravarty and L Lefeber, op cit). Apart from these programming models, several models of the consistent requirements type have been based on a 30 sector interindustry classification (see, for example, A S Manne and A Rudra, "A Consistency Model of India's Fourth Plan", "Sankhya" (February 1965).

3 All references to calendar years are understood to apply actually to the fiscal year which runs from April 1 to March 31; thus 1975 denotes the fiscal year 1975-76.

4 Work is now in progress on an extension of the model to incorporate choice of exporting activities with diminishing marginal earnings of foreign exchange.

5 The stock-flow conversion factor expresses the level of investment in the target year as a proportion of the cumulative investment requirements over the whole period. It is estimated on the assumption that the post-terminal rate of growth of the economy will be consistent with the predetermined rate of growth of consumption between the base and the target year.

6 Because of the great number of coefficients required for the implementation of the model (there were approximately 5000 matrix entries in the final form of the linear programming problem), it is quite possible that isolated numerical errors may have crept in at various stages of the study. Hence the precise results at the sectoral level presented in Tables 3 and 4 should be regarded as preliminary and subject to cross-checking.

7 It is theoretically possible for the model to prefer imports to domestic production in a foreign exchange minimizing solution if the minimal foreign exchange content of domestic production actually exceeds the corresponding import price. That this was not the case here can be varified in Table 4.

8 The remaining domestic production activities that compete with imports all had percentages of less than 30 per cent under the initial set of assumptions.

9 The net inflow of foreign capital is defined in this exercise simply as the balance of trade deficit on merchandise account, excluding the import of foodgrains and military supplies. To the extent that foreign exchange is required for the latter items, or for any net payments under invisibles, an additional inflow of foreign capital would be called for.

10 Because they actually represent a series of discrete steps, these lines should not really be continuous but piece-wise linear.

11 H Chenery and M Bruno, "Development Alternatives in an Open Economy: the Case of Isreal", "Economic Journal" (March, 1962).

12 R I McKinnon, "Foreign Exchange Constraints in Economic Development and Efficient Aid Allocation", "Economic Journal" (June, 1964).

13 H Chenery and A Strout, "Foreign Assistance and Economic Development", "American Economic Review" (September, 1966).

14 See R I McKinnon, op cit, for a concise discussion with references to, earlier work.

15 The assumption of a single capital-output ratio and a single import coefficient could be relaxed to accomodate different coefficients associated with consumption and investment; the basic character of the aggregative model, as well as the conclusions, would remain unaffected.

16 The incremental capital-output ratios listed in Table 5 were calculated by relating the total cumulative gross investment requirements from 1963 to 1973 to the increase in aggregate production capacity from 1965 to 1975; thus a two-year average investment-output lag was assumed. The actual figures obtained depend on an estimate of the extent to which overall capacity exceeded actual output in the Indian economy in 1965. Since any such estimate is necessarily very uncertain, the absolute values given in the table should be interpreted with some caution. More reliance can be placed on relative values, which are in any case the more significant from the point of view of the analysis.

17 See footnote 5 above.

18 I am indebted to S Chakravarty for emphasizing this point.

19 For a contrary view, See V Joshi, "Foreign Exchange Bottlenecks" "Economic and Political Weekly", (March 4, 1967).