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Planning for Sectors and Projects in Developing Countries: Applications of the Semi-Input-Output Method[1]

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This article presents a special case of W. Leontief's traditional input-output techniques, viz., J. Tinbergen's semi-input-output method. Particularly suitable for planning purposes in developing countries with open economies, the method emphasizes the role of a country's comparative advantages for investment decisions at both the sector and project level. The similarity of semi-input-output with the Little-Mirrlees method of shadow pricing is shown. Empirical applications for Nigeria are reviewed.

I. INTRODUCTION

Inter-industry or input-output analysis is being increasingly applied as an important technique used in many developing countries in both industrial and economy-wide planning. As a result, a variety of models meant for planning at the sector level have been developed in which intersectoral linkages based on input-output relations figure prominently. In this article a special case of W. Leontief's traditional input-output techniques will be presented, viz. J. Tinbergen's semi-input-output method. Particularly suitable for planning purposes in LDCs with open economies, the method emphasizes the role of a country's comparative advantages for investment decisions. The method is typically relevant for *ex ante* resource-allocation decisions concerning the creation of new capacity and can be appropriately applied at both the sector level and project level of planning.

The special character of the semi-input-output method derives from the distinction between international and national sectors, a distinction based on the mobility of commodities produced, and similar to I.M.D. Little's distinction between tradeable and non-tradeable goods. Whereas in traditional input-output analysis the calculation of indirect effects is based on existing intersectoral linkages, the semi-input-output method confines indirect production effects to those sectors where

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[1]This article is a revised and extended version of an earlier paper [6]. It is partly based on the author's book [7] to which the reader is referred for a more detailed analysis and application of the method.

input-output method confines indirect production effects to those sectors where they necessarily occur, viz. the *national* sectors. In these sectors, non-tradeable goods are to be produced domestically because no alternative source of supply is available. By contrast, demand for international goods can in principle be met from international trade, and input-output relations between *international* sectors are therefore not considered relevant for production and investment decisions. It can be argued that indirect effects of capacity expansions in international activities should not include assumed capacity effects on other international sectors, the desirability of which is subject to separate investment decisions.

Before the semi-input-output method is presented selected planning techniques for sectors and projects are reviewed. Following Tinbergen, different stages in development planning are proposed, sectoral and project planning are treated in more detail, and a brief attempt is made to indicate how possible inconsistencies between the sector and project stage in the allocation of resources can be removed. The semi-input-output method itself is presented next. Its basic concepts are discussed and the planning implications compared with other approaches such as Nurkse's and Hirschman's. Applications of the method at the sector level are discussed, in particular the estimation of indirect effects and the use of linkage criteria. The major differences with Leontief's input-output model are numerically illustrated. Applications at the project stage are then given. Special attention is paid to the estimation of accounting prices for national, non-tradable goods and the similarity with the Little-Mirrlees method of shadow pricing is shown. The study concludes with a review of empirical applications of the method to Nigeria.

II. PLANNING FOR SECTORS AND PROJECTS

Development planning can be defined as the preparation and co-ordination of medium- and long-term economic policy by those government institutions involved in the formulation, implementation or execution of development policy. The latter is supposed to include the formulation of development objectives as well as the selection of instruments of development policy which government institutions are able and willing to apply. The choice of both targets and instruments will reflect, of course, value judgements made by policy-makers. Because in most LDCs the outcome of the development process is not exclusively left to the market, development planning is, in one way or another, nowadays applied by a host of countries adhering to widely varying economic systems.

As development planning normally deals with a variety of socio-economic problems involving a fair number of government institutions, economy-wide development planning can be a complicated matter. The recognition of the latter has led to different approaches towards the kind of models to be designed for the planning of economic development. One approach is to fully accept the interdependence of various problems and to use detailed mathematical models of a high degree of complexity to solve all problems simultaneously. Other approaches, while acknowledging interdependencies, have concentrated on ways to simplify the complex questions in development planning by decomposing them into separate though not independent problems. In this context, Tinbergen [14] has proposed to distinguish a number of consecutive stages in development planning which are characterized by a different degree of aggregation, namely

(i) a *macro* stage, in which the development of the main economic and financial aggregates is determined;

(ii) a *middle* stage, in which the expansion of different industries and their regional distribution is considered; if the regional aspect is treated separately this stage can be called the *sector* stage; and

(iii) a *project* stage, in which investment projects are selected and their location is determined.

Depending on the way the planning process is organized, results for a particular stage should be carefully checked against those of other stages. With top-down planning the results of some of the preceding stages may have to be reconsidered in the light of the findings for later stages. As information is usually much more precise at the micro stages of planning, ample opportunities for feed-back into the more aggregate stages will have to be allowed for. Through iteration and reiteration the formulation of a plan can then be gradually improved.[2]

In practical planning exercises the relevance of distinguishing several stages in the planning process will depend on a number of factors such as the size of the country, the location of economic activities, international trading opportunities, natural endowments, special skills, economic system and institutions, nature and characteristics of projects to be developed, etc. Thus, in a small and homogeneous country there might be no need for a middle stage and planning may be confined to the macro and project stage. In contrast, countries with a large and spatially dispersed market may find it useful to work with all stages of planning to keep matters comprehensible. Similarly, if sectors are fairly homogeneous, planning at the sector and project level may largely coincide; if not, as is often the case in agriculture and manufacturing, sectoral priorities and policies are typically prepared at a more aggregate (sector) level whereas most investment decisions are taken at the micro level. Both examples, incidentally, point to a major dichotomy in the planning process, viz. the basic difference between the project stage and other stages of planning. If a project is defined as the smallest technically independent unit of production, the other stages are characterized by different *degrees* of aggregation of the very units that are the subject matter of micro-economic analysis at the project stage.

[2] Little and Mirrlees [10, Ch. 6] give a vivid description of the interaction between aggregate plans and projects. See also [16, Chaps. 1 & 11].

Sectoral Planning

At each stage of the planning process, special techniques are employed to analyse the corresponding planning problems. At the *sectoral* stage, in which the main problem is to determine which industries should be developed or expanded, and to what extent, interindustry analysis is widely recognized as a powerful analytical planning technique. Over the years, a variety of economy-wide multi-sectoral models have been developed in which input-output relations usually play an important role. Increasing experience with such models has led to a growing similarity in their general framework enabling routine applications on a fairly large scale [4; 13]. Without such models, it seems hardly possible to estimate changes in the composition of demand, in the sectoral distribution of production and investment, and in a country's trade pattern in a consistent way, i.e. avoiding shortages in some sectors and surpluses in others. Moreover, requirements of intersectoral consistency in the presence of non-substitutability between sectors often put additional constraints on the rate of growth of an economy, causing an upward bias in estimates obtained with more aggregative methods. Finally, the use of an input-output framework offers a useful basis for discussion between project or sector specialists and those concerned with macro-economic analysis and planning [13, p. 42].

At the same time, however, there is a growing awareness of the limitations of the results of empirical applications to LDCs, both with regard to the sector level itself as well as other levels of planning. *Stability of the structural coefficients poses* a first problem. Input-output, capital-output and labour coefficients are normally estimated on the basis of data from some recent period. The inevitable time-lag between the last period of observation and the period to which the planning exercise refers becomes a major cause for concern in those countries where more than marginal additions to existing industries and rapid changes in technology may very well affect the stability of input coefficients.

A second major problem concerns the *homogeneity of the sectors* distinguished, and is closely related to the aggregation problem. Theoretically, the basis for aggregating commodities is either similarity in input structuro or output proportionality. When thousands of commodities are aggregated into a limited number of sectors, it is an empirical matter whether those requirements are reasonably met. Several empirical studies suggest, however, that at the usual level of aggregation in input-output analysis, heterogeneity of sectors might be such that the variance in economic characteristics among commodities within the same sector is larger than among sectors themselves.

Another set of problems arises when multisectoral models are specified as *linear programming* models. Following Taylor [13, p. 59], the structure of applied planning models of this kind can usually be characterised by three kinds of restrictions. First, there are the real limitations on economic growth posed by the availability of primary factors of production, foreign exchange, and the input-output balances. A second type of constraint is meant to reflect 'important but not well-understood limitations on growth' which are partly of a non-economic nature (absorptive capacity constraints, minimum consumption and employment requirements, protection, etc.). Thirdly, *ad hoc* restrictions are included to avoid over-specialization in foreign trade and other forms of extreme behaviour implied by linear systems. Given the nature of the restrictions of the second and third type, the usefulness of such planning models lies primarily in their indication of broad areas of sectoral choice rather than in exact optimal solutions for the development of sectors.

Similar qualifications apply to the dual solution. As a result of model specification, small changes in the primal may cause large and discontinuous changes in the dual. The dual of an optimizing model of this kind should therefore primarily be used to check the structure of the model and the nature of the primal solution. Any additional claims such as their interpretation as accounting prices for project appraisal or their association with a competitive equilibrium seem too ambitious at the present state of the art [3; 11].

Given these criticisms, the question obviously arises about the role economy-wide multisectoral models can actually play in the planning process. Before answering this question it should be emphasized that the first two criticisms are partly of an empirical nature, i.e., their relevance can only be judged in a specific case, whereas the other objections point to theoretical limitations which are bound to influence the results in any case. If, for whatever reason, the empirical nature of the first two objections is bypassed, one arrives at a minimum position with regard to the role of multisectoral models. of which the views as expressed in Little and Mirrlees [10] are a good example. In their opinion, the planning process is characterized by the interaction of macro-economic planning based on aggregate analysis and micro-economic planning at the sectoral (if there exist economies of scale) and project level using partial analysis. With more and better information coming up from individual projects, tentative estimates of the development of economic aggregates can be improved, which, in turn, should permit improvement in project analysis and appraisal.

While correctly emphasizing the importance of project analysis in the process of planning, this position clearly underestimates the organizational and analytical difficulties of arriving at an optimum or even consistent plan on the basis of project data and partial analysis alone. Traditional input-output techniques, for example, provide for intersectoral consistency, enable the derivation of an implicit price system, and can be a starting point for linking macro and micro results. Disaggregation of heterogeneous sectors and updating or replacing original input data may successfully remedy some of the empirical shortcomings of applying input-output techniques in LDCs.

Project Planning

The project stage of planning, in which investment projects are identified, prepared and appraised, shows that project planning can generally be considered the most concrete stage of planning. The degree of detail and quality of the data usually enables a much more precise analysis than at the previous stages of planning. Thus, the appraisal of projects can be based on criteria that reflect the objectives of development policy, all relevant scarce factors, and take account of particular conditions of application. When the number of projects appraised in this way takes up a significant part of the investable resources, systematic project planning has two important implications for the sector stage: (i) it leads to a substantial improvement of the available information on sectoral coefficients, and, hence, of the estimation of effects, in particular indirect or linkage effects; and (ii) it enables a refinement of sectoral criteria of attractiveness, either based on partial analysis or derived from economy-wide multi-sector models. As a result, the consistency between the outcome of planning exercises at the sectoral and project level can be improved.

Once accepted and implemented, a project increases the supply of outputs by using a specific combination of inputs which could have been used elsewhere in the economy. Without the project, the demand for inputs and the supply of outputs would have been different in the rest of the economy. By comparing the differences between a situation with and without the project, the benefits and costs associated with the project can in principle be identified, on the basis of which it can be decided whether the proposed use of resources is justified or not. Two steps can usually be distinguished in this procedure: (i) estimating the changes in the economy caused by a particular project (the effects of the project); and (ii) considering what these changes are worth (to the investor, the government, social groups) by comparing them with alternative changes that would have occurred in the rest of the economy without the proposed project.

Direct effects of a project are defined to refer to the physical inputs and outputs of the project and follow as a rule from the project's technical characteristics. *Other* important consequences of a project for the rest of the economy include the necessary domestic adjustments on the supply side (indirect or linkage effects), effects which represent a benefit or cost for the society but not necessarily for the project (external effects), price effects, and distributional effects.

Generally, the valuation of relevant project effects is not an unambiguous matter but depends on the objectives and constraints of decision-makers and social groups concerned. For a profit-maximising private investor the actual or expected receipts and expenditures resulting from a project are the relevant benefits and costs, implying the valuation of project effects at actual or expected market prices. For national planning purposes, however, the valuation of project effects should reflect the ultimate contribution to or detraction from the society's objectives. In developing countries, market prices can usually not be expected to reflect true or real project costs and benefits to society, because they often result from highly distorted markets in which society's objectives are at best partly reflected. Instead, a set of accounting prices will normally have to be estimated, indicating the real costs of inputs and the real benefits of outputs to society including, when necessary, the distributional aspects mentioned above.

In this connection, it is sometimes argued that the introduction of other than direct effects in the appraisal and selection of projects can be taken as a substitute for the use of factor accounting prices. This position, as shown by Balassa [1] for the case of the 'effects' method of Prou and Chervel, appears incorrect. If markets are perfectly competitive, all factors of production are fully utilised, project changes are marginal and not subject to increasing returns, no external effects occur, and the government is indifferent as to whom project income accrues and how it is spent, actual project receipts and expenditures can be expected to measure the true benefits and costs to society. Under these assumptions, the project's direct net benefits (profits) as measured through market prices are a correct indication of the gain to society, and other than direct effects, if they occur at all, need not be considered because they can be thought to be properly reflected in the prevailing market prices. If markets for commodities and factors are seriously distorted, market prices cannot be considered a good indicator of a project's gain to society and will fail to reflect the full consequences of a project. For national planning purposes, a corrective set of accounting prices will therefore have to be substituted for the prevailing market prices. It is important to realize that such prices do not represent equilibrium prices ruling in a distortion-free economy, but relate to a situation in which distortions are likely to persist.

It should be emphasized that the calculation of project effects is independent of the use of accounting prices. The latter partly depend on value judgements on the side of the government as well as resource and policy constraints judged to be relevant which are not necessarily reflected in the calculation of other than direct effects. The inclusion of those effects in project appraisal can therefore not be taken as a substitute for using accounting prices. On the other hand, depending on the way accounting prices are actually estimated, it cannot be excluded that they substitute for some of the indirect and other effects.

Consistency Considerations

A comparison of the methods of sectoral and project analysis described above shows that possible inconsistencies in the allocation of resources mainly arise from two partly interrelated sources: (i) the use of different sets of accounting prices, reflecting in part policy constraints and objectives judged to be relevant by policy-makers; and (ii) the different number of scarce resources distinguished. To reduce such inconsistencies apply as much as possible the same system for determining accounting prices at the project and at the sector stage. To this effect, the price models which underlie recent methods of project appraisal [9; 10; 12; 16; 17] can serve as a suitable point of departure for accounting price determination at the sector level. As a first approach, input-output flows and corresponding structural coefficients can then be revalued by expressing them in new units of measurement based on estimated accounting prices.

As to the second source of inconsistencies, the number of primary resources distinguished at the sector level is usually smaller than at the project level where, in principle, all primary factors into a project should be appropriately costed. As the non-distinguished primary factors are implicitly valued at a zero accounting price, the net benefits identified at the sector level might differ from those at the project level. When, for example, benefits at the sector level are defined as the contribution to national income, and, at the same time, a measure of social income or profit is defined as the net benefit at the project level, inconsistencies are bound to arise. In this case, sectoral benefits should be reformulated as much as possible in terms of social income or social profit in the Little-Mirrlees or UNIDO sense instead of using sectoral value added. In this approach, accounting prices for primary factors derive in principle from a general equilibrium framework (although the actual estimation procedure includes a number of shortcuts).

III. THE SEMI-INPUT-OUTPUT METHOD

A particular method of development planning at the sector and project level is the *semi-input-output method*. Introduced by Tinbergen in the early 1960s, the method aims at solving the closely related problems of efficiency in production and international trade through the right choice of sectors and projects to be developed. Particularly suitable for those developing countries with open economies, the method explicitly emphasizes the role of a country's comparative advantages for investment decisions. Through appropriate shadow pricing, the international competitiveness of new activities is brought into the planning process from the very beginning.

As the name suggests, the semi-input-output method can be considered a special case of W. Leontief's traditional input-output techniques. Its special character derives from the distinction between international and national sectors, a distinction based on the mobility or transportability of the commodities produced. The distinction derives from the assumption that for each good a spatial unit can be defined within which the good can be considered mobile because its transportation costs are negligible, and outside which it can be regarded as immobile because transportation costs would be prohibitive.

It follows that the tradeability of a good can now be defined in relation to the largest spatial unit for which the good can still be regarded as mobile. Depending on the nature and size of the spatial units, goods may therefore be approximately classified as local, regional, national or international. Goods for which transportation costs never become prohibitive can be defined as international goods. Confining ourselves to national economies, only international and national goods (including

regional and local goods) need to be distinguished, a distinction which, in this special case, coincides with the one between tradeable and non-tradeable goods as introduced by I. M. D. Little.

In traditional input-output analysis the calculation of indirect effects is based on existing intersectoral linkages. With the semi-input-output method, however, indirect effects are confined to those sectors where they necessarily and unavoidably occur, viz. between the *national* sectors. Lacking any alternative source of supply, the production of national goods must be expanded in accordance with increased demand, which, to a large extent, is caused by production expansions in the international sectors as will be shown below.

Changes in demand for international goods can in principle be balanced by international trade, and input-output relations between *international* sectors are therefore not considered relevant for production and investment decisions – for the simple reason that the mere presence of domestic demand for international products is not a sufficient condition to create productive capacity (as it is in the case of national goods). The decision to expand an international sector should be based on a country's primary resources (determining its comparative advantages in international trade) and its development objectives. Indirect effects of such a capacity expansion should not include assumed capacity effects on other international sectors, the desirability of which is subject to separate investment decisions. Including these assumed capacity effects would imply that different investment decisions are mixed up.

Empirically, the relative importance of national sectors can be shown to be considerable. For selected countries of the European Community 55 – 65 percent of value added and 47 – 54 percent of output originates in the national sectors. For selected developing countries the relative shares show a much wider variation, mainly depending on the importance of agriculture and mining: 33 – 64 percent for value added, and 34 – 54 percent for output. Combining these results shows that the relative share of national activities apparently assumes a maximum value of about 65 percent of aggregate income and 55 percent of aggregate output. Substantially lower values obtain for countries with a high relative share of primary activities.

A Simple Multisectoral Model

To illustrate the semi-input-output method and to facilitate a comparison with other methods of development planning, we start out from a simple input-output system in which N sectors are distinguished. The corresponding balance equations can be written as

$$x_N = A_{NN}\, x_N + j_N + f_N + e_N \qquad \ldots \qquad (1).$$

where

x_N = vector of increases in output in N sectors during a planning period,
j_N = vector of increases in sectoral deliveries of capital goods,
e_N = vector of changes in sectoral exports minus imports,
f_N = vector of increases in sectoral final demand other than for investment and export goods, and
A_{NN} = matrix of technical input-output coefficients, element α_{ij} (i = j = 1, ... , N) denotes current input of good i per unit of output of sector j.

Eq. (1) shows that a particular commodity i can be used for intermediate purposes, i.e. for deliveries of inputs into current production of all sectors, and for final purposes. Intermediate demand is determined by technical input-output coefficients α_{ij} and the change in the level of output of all productive sectors x_j. Thus, total intermediate demand for commodity i adds up to $\sum_{j=1}^{N} \alpha_{ij} x_j$ units. The increase in final demand other than for investment and export purposes is considered exogenous. As the sum of the changes in the different uses to which a commodity can be put equals the change in domestic and foreign supply, the trade variables e_i act as a balancing item once the changes in sectoral output x_i are known. When positive they are used to meet foreign demand for commodity i, when negative they represent additional foreign supply (imports) to supplement domestic supply.

Assuming that there is no general excess capacity at the beginning of the planning period, increases in output will require capacity expansions of which the corresponding increase in demand for various capital goods can be described as

$$j_N = h\,K_{NN}\,x_N - \bar{j}_{oN} \qquad \qquad (2)$$

where

K_{NN} = matrix of partial capital-output ratios, element κ_{ij} (i = j = 1, . . ., N) denotes investment of good i per unit output of sector j,
h = capital stock-flow conversion factor, and
$\bar{j}_{oN}$ = vector of the level of sectoral deliveries of investment goods from existing capacity at the beginning of the planning period.

Investment eq. (2) shows that a production expansion x_j will require different capital goods i as indicated by the partial capital-output ratios κ_{ij}. The total demand for capital good i will therefore amount to $\sum_{j=1}^{N} \kappa_{ij} x_j$, which will be met from existing capacity to the extent indicated by $\bar{j}_{oi}$ as well as from increments in capacity during the planning period enabling the supply of an additional amount j_i. The cumulated annual investment flows required for the increase in output during the planning period are related to the level of terminal year investment $\bar{j}_T = \bar{j}_o + j$ through a uniform stock-flow conversion factor h.

Substituting eq. (2) into eq. (1) gives

$$x_N = H_{NN}\,x_N - \bar{j}_{oN} + f_N + e_N \qquad \qquad (3)$$

where $H_{NN} = A_{NN} + h\,K_{NN}$

showing that deliveries on both current and capital account have been added in a single parameter $\eta_{ij} = \alpha_{ij} + h\,\kappa_{ij}$.

We now introduce the distinction between international and national sectors by splitting the N productive sectors into F international and D national sectors (F + D = N). As a result, eqs. (1) and (2) can be reformulated by partitioning them into an international and a national part, enabling eq. (3) to be rewritten as

$$x_F = H_{FF}\,x_F + H_{FD}\,x_D - \bar{j}_{oF} + f_F + e_F \qquad \qquad (4)$$

and

$$x_D = H_{DF}\,x_F + H_{DD}\,x_D - \bar{j}_{oD} + f_D \qquad \qquad (5)$$

Characteristically, no trade variables appear in the balance equations for the national sectors, and the general solution for the increases in output of the national sectors, including the complementary indirect production effects on the national sectors caused by planned production expansions x_F in the international sectors, can be found by solving eq. (5):

$$x_D = (I_{DD} - H_{DD})^{-1}\,(H_{DF}\,x_F - \bar{j}_{oD} + f_D) \qquad \qquad (6)$$

Notice that in the national investment goods sectors (in which $\bar{j}_{oi} > 0$) total production effects exceed total capacity effects by $(I_{DD} - H_{DD})^{-1}\bar{j}_{oD}$ units.

For a particular capacity expansion x_e in international sector e, the capacity effect on the national sectors will be defined as the marginal increase in capacity $x_{D,e}$ complementary to the planned increase in capacity x_e. It follows then directly from eq. (6) that

$$x_{D,e} = (I_{DD} - H_{DD})^{-1}\,\eta_{D,e}\,x_e \qquad \qquad (7)$$

where $\eta_{D,e}$ is the e-th column of sub-matrix H_{DF} of national inputs into international sectors. As there is no alternative source of supply for the national sectors, any capacity expansion in an international sector entails a number of complementary production effects on the D national sectors, caused by the demand for national (current and capital) inputs $\eta_{D,e}$ into international sector e. In the usual input-output fashion, the latter are augmented by indirect production effects caused by interdependencies among the national sectors as shown by the inverse $(I_{DD} - H_{DD})^{-1}$. For the calculation of the cumulative production effects, only the *national* part of the relevant input-output matrix is thus used, hence the name of the method as *semi*-input-output method.

In principle, no indirect production effects comparable to those in the national sectors occur in the international sectors because their interdependencies in production are broken by the possibility of international trade. As shown in eq. (4), any effect of a planned capacity expansion in an international sector (directly through sub-matrix H_{FF} or indirectly through the effects on the national part of the economy as indicated by sub-matrix H_{FD}) on the demand for other international goods can be met be either increased production or imports. Due to the tradeability of international goods, capacity expansions in the international sectors can therefore be considered independently of each other. At the same time, however, no capacity expansion in an international sector can be considered in isolation because of its complementary effects on the national sectors. As shown by vector $\eta_{D,e}$, the latter are generally specific for each international sector and, together with the international capacity expansion, make up what can be called a *bunch* of complementary activities.

Planning Implications

Turning to the planning implications of the semi-input-output method, the model presented above, though highly simplified, serves to illustrate two important implications of the method.

(1) Lacking any alternative source of supply, the production of the *national* sectors must be expanded in accordance with increased demand, which is, to a large extent, caused by the capacity expansions in international sectors. Hence, planning of national sectors should be based on demand forecasts and cost effectiveness if alternative techniques are available.

(2) Input-output relations between international sectors are not considered relevant for production decisions as long as it is possible to meet additional demand for international products from imports. Under a system of perfect foreign trade, the decision to expand an *international* sector should be based on considerations with regard to a country's primary resources and development goals as reflected in the corresponding bunches of activities. With the possibility of international trade, the mere presence of domestic demand for international products can never be a justification for creating productive capacity, as it is in the case of national goods.

One of the implications of the method just mentioned, viz. that the expansion of production of the national sectors should be in proportion to the expansion of demand for their products, exactly corresponds with Nurkse's concept of 'balanced growth'. Hence, as far as the *national* sectors are concerned, Nurkse's recommendation of balanced growth conceptually agrees with that of the semi-input-output method.

The implied independence of the expansion of international sectors of the presence of linkages between them contrasts sharply with Hirschman's model of economic development. In Hirschman's view, the scarcest resource in developing countries is decision-making ability, in particular with regard to investment decisions. The appropriate strategy to be followed in this case would be to induce such decisions through a set of mechanisms, of which Hirschman emphasises two. First, the establishment of an activity which requires substantial amounts of fabricated intermediate inputs is assumed to induce investment opportunities in the sectors producing these inputs. Because of the growing demand for these inputs, the expansion of domestic production is expected to be encouraged in order to supply the additional inputs. Hirschman calls this effect the backward linkage effect; it can be measured by the ratio of purchased intermediate inputs to the total cost of production. Second, the output of the newly established activity is believed to induce production expansions in those sectors which use the outputs as inputs in other new activities. This is the forward linkage effect, measured by the ratio of intermediate deliveries to total demand. Both effects measure direct production effects only; the total linkage effect, including all indirect effects, can be measured by the traditional Leontief inverse.[3]

The potential linkage generation of the different sectors can now be used to rank sectors in order of priority. In terms of development strategy, highest priority is assigned to those sectors having both high backward and high forward linkages. In Hirschman's view, concentrating on these sectors will deliberately cause some imbalance in the economy, which serves to underline the investment opportunities for businessmen. In this way, potential savings might be mobilized and channeled into investment, decision-making ability will develop in a learning process, and growth will be stimulated by breaking bottle-necks created by supply shortages ('unbalanced growth').

A comparison of Hirschman's concept of sectoral linkages with that implied by the semi-input-output method, viz. the complementary bunches of activities, shows several major differences. For new activities the sectoral linkages as defined by Hirschman suggest potential investment opportunities based on the technical characteristics of the production processes. However, to the extent that goods can only be supplied domestically, as in the case of national products, the production effects on the national sectors are unavoidable and compulsory, a phenomenon clearly put forward by the semi-input-output method. In view of the continuous difficulties in keeping the supply of national goods in line with demand in most developing

[3] In the symbols of this section, where A stands for the full matrix of technical input-output coefficients, $(I-A)^{-1}$ is defined as the Leontief inverse.

countries (construction, electricity, water, transport, education), the necessary investment to increase productive capacity in those sectors should be planned well in advance in order to balance supply and demand.

On the other hand, the potential production effects on the international sectors, indicating possible investment opportunities, can be rather misleading with respect to the efficient allocation of resources. In view of a country's prevailing relative scarcities, it can be efficient to avoid a number of backward linkages and to import the technically necessary inputs instead (though the actual tariff structure might encourage domestic production so that private and social profitability may be conflicting). In addition, production expansions in an international sector should not only be considered if domestic demand increases, the possibility of exporting goods should also be taken into account. Hence, a country's comparative advantage in foreign trade based on the corresponding complementary bunches of activities, not the input-output linkages between international sectors, should determine their expansion.

IV. APPLICATIONS AT THE SECTORAL STAGE

The significance of the semi-input-output method for planning purposes, both at the sector and project stage, lies in its ability to permit a systematic treatment of efficiency in production and international trade. As explained in the preceding section, the method emphasizes that (i) the real choice in development is among international activities, and (ii) each investment project in an international sector can only be considered in combination with complementary investment in the national sectors. The determination of the composition of complementary bunches of investment connected with a capacity expansion in an international sector can thus be considered one of the major contributions of the semi-input-output method at the sectoral level of planning. Once the exact composition of the complementary bunches is known, its significance is twofold: (i) the (bunch) effects of a sectoral capacity expansion can be properly determined, and (ii) the attractiveness of sectoral capacity expansions can be established by valuing benefit and cost items among the (bunch) effects, enabling the identification and selection of sectors to be expanded.

As a planning method, semi-input-output is thus primarily concerned with the *choice* of sectors to be developed or expanded and the *selection* of projects on the basis of a country's comparative advantage, i.e. by specializing in those activities in which a country is able to compete in the world market by exports and import substitutes. For a given selection criterion, the semi-input-output method can thus be considered a special way of optimal investment allocation. At the sectoral level the method enables the ranking of international sectors according to a criterion of attractiveness. It should be emphasized, however, that it does not solve the question of the desired *level* of expansion of the international sectors. Unless the sectoral increases in capacity are completely built up from individual projects, or complete

specialization at the sectoral level occurs, the problem of sectoral expansions still remains to be solved. Extending the method into a more comprehensive one enabling an explanation of changes in capacity in the international sectors themselves inevitably results in the construction of conventional input-output or programming models.

Although the inability to determine changes in the sectoral composition of production is a clear limitation of the semi-input-output method, it should be emphasized that the actual determination of sectoral capacity expansions is one of the most demanding exercises in the planning process for which, at the level of disaggregation usually required, no single technique can claim to give a satisfactory answer yet. Because semi-input-output is less comprehensive than economy-wide models and relatively simple to apply, the method can be used at a high level of disaggregation enabling the identification and appraisal of a large number of industries at the three- or four-digit level in which a country might have a comparative advantage.

Estimation of Complementary Effects

To explain the *estimation of complementary effects*, a numerical example will be presented in which the direct and indirect effects according to semi-input-output and traditional input-output analysis are calculated. The various effects of a unit capacity expansion in sector j will be denoted by a general symbol β_j. The direct effect of a unit capacity expansion x_e in international sector e on investment, employment, value added, profits, etc. is then given by β_e. With the semi-input-output method, the indirect production effects $x_{D,e}$ are confined to the national sectors and the total effect of a complementary bunch of activities can be written as (see eq. (7))

$$\tilde{\beta}_e = \beta_e + \beta_D'(I_{DD} - H_{DD})^{-1}\eta_{D,e} = \beta_e + \beta_D'\bar{\eta}_{D,e} \quad \ldots \quad \ldots \quad (8)$$

where, in addition to the symbols defined, vector $\tilde{\bar{\eta}}_{D,e}$ expresses the cumulative capacity effect on the national sectors. Henceforth, $\tilde{\beta}_e$ will be called the *bunch effect.*

In traditional input-output analysis, indirect effects occur in all productive sectors and the comparable total effect of a unit increase in final demand for a good produced by sector e amounts to

$$\bar{\beta}_e = \beta_N'(I_{NN} - H_{NN})^{-1}\iota_{N,e} \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

where vector $\iota_{N,e}$ is a unit vector with the e-th element equal to unity.[4] Because it includes the effects of all sectors, $\bar{\beta}_e$ will henceforth be called the *total effect.* For a

[4] With the semi-input-output method, a unit increase in final demand f_e is, by assumption, identical to a unit capacity expansion x_e in *international* sector e.

'well-behaved' matrix H_{NN}, the inverse in eq. (9) can be written as an expansion in powers according to

$$(I_{NN} - H_{NN})^{-1} = I_{NN} + H_{NN} + H^2_{NN} + \ldots = I_{NN} + H^s_{NN}$$

enabling the direct and indirect effects to be written separately as

$$\bar{\beta}_e = \beta_e + \beta_N' \, \eta^s_{N,e} \qquad \ldots \qquad \ldots \qquad \ldots (10)$$

where vector $\eta^s_{N,e}$ is the e-th column of matrix H^s_{NN}.

When matrix H_{NN} includes imports, the effects $\bar{\beta}_e$ are obviously maximum estimates because they include the additional production effects of previously imported commodities. One way to correct for this is to fix the relation between domestically produced and imported commodities and to subtract competitive imports from sub-matrix H_{FN} (it is assumed that non-competitive imports are already excluded). The lower estimates $\bar{\beta}^d_e$ now refer to a situation in which the domestic input structure of production remains unchanged during the planning period.

A careful comparison of eqs. (8) and (9) shows how semi-input-output emerges as a special case of traditional input-output analysis when the assumption is made that all imports and domestic production of international sectors are perfect substitutes so that the entire sub-matrix H_{FN} vanishes. For this assumption, the solution of the inverse in eq. (9) becomes a special case of the general method of inverting a matrix by partitioning, viz.

$$\left[\begin{array}{c|c} I_{FF} & 0 \\ \hline -H_{DF} & I_{DD} - H_{DD} \end{array}\right]^{-1} = \left[\begin{array}{c|c} I_{FF} & 0 \\ \hline (I_{DD} - H_{DD})^{-1} H_{DF} & (I_{DD} - H_{DD})^{-1} \end{array}\right]$$

Applying this special case of matrix inversion to eq. (9) gives eq. (8).

In the numerical example four productive sectors are distinguished: sectors 1 and 2 produce international and sectors 3 and 4 national goods. Capital goods originate in sectors 2 and 4. No complementary imports are distinguished. Value added consists of wage income and profits. The matrices of technical input-output coefficients A_{NN} and of partial capital-output ratios K_{NN}, and the vectors of value added coefficients α_{oN}, of profit-output ratios ζ_N, and of capital-output ratios κ_N are given as

$$A_{NN} = \left[\begin{array}{cc|cc} 0.1 & \begin{array}{c}0.3\\(0.1)\end{array} & 0.1 & \begin{array}{c}0.3\\(0.1)\end{array} \\ \begin{array}{c}0.1\\(0.1)\end{array} & \begin{array}{c}0.2\\(0.1)\end{array} & \begin{array}{c}0.1\\(0.1)\end{array} & 0 \\ \hline 0 & 0.2 & 0.2 & 0.1 \\ 0.2 & 0 & 0 & 0.2 \end{array}\right]$$

$$K_{NN} = \left[\begin{array}{cc|cc} 0 & 0 & 0 & 0 \\ \begin{array}{c}1.2\\(0.8)\end{array} & \begin{array}{c}0.4\\(0.4)\end{array} & \begin{array}{c}1.0\\(0.8)\end{array} & \begin{array}{c}0.4\\(0.4)\end{array} \\ \hline 0 & 0 & 0 & 0 \\ 0.6 & 0.2 & 2.0 & 0 \end{array}\right]$$

$$\alpha'_{oN} = \left[\begin{array}{cc|cc} 0.6 & 0.3 & 0.6 & 0.4 \end{array}\right]$$

$$\zeta'_{oN} = \left[\begin{array}{cc|cc} 0.3 & 0.2 & 0.4 & 0.1 \end{array}\right]$$

$$\kappa'_N = \left[\begin{array}{cc|cc} 1.8 & 0.6 & 3.0 & 0.4 \end{array}\right]$$

Figures between brackets indicate assumed imports. The value of the capital stock-flow conversion factor h is put at 0.15. For the sake of convenience, coefficients are assumed to have been estimated from input-output flows measured in actual market prices. Hence, the sectoral value added coefficients are defined as $\alpha'_{oN} = u'_N (I_{NN} - A_{NN})$ and the sectoral capital-output ratios as $\kappa'_N = u'_N K_{NN}$, where u'_N is a sum vector.

Estimates of direct and indirect effects according to eqs. (8) and (9) for investment, value added and profits are presented in Table 1.

The difference in the size of the indirect effects between semi-input-output and traditional input-output analysis is clearly brought about in the last three columns of Table 1, and follows, of course, from the assumed difference in the structure of interindustry linkages. With the semi-input-output method, production effects of increased demand for international goods are, by assumption, excluded, and indirect effects are invariably smaller than in the case of traditional input-output analysis. When total effects are calculated on the assumption that all import leakages have vanished, a further increase in the size of the indirect effects occurs as shown in the last column of Table 1.

For the calculation of indirect effects, the major difference in approach between Leontief's traditional input-output analysis and Tinbergen's semi-input-

Table 1

Direct and Indirect Effects of a Unit Capacity Expansion in International Sector e according to Semi-input-output and Traditional Input-output Analysis

Effect on	Sector expanded	Direct effect (β_e)	Semi-input-output ($\tilde{\beta}_e$)	Traditional input-output ($\bar{\beta}^d_e$)	Traditional input-output ($\bar{\beta}_e$)
Investment	1	1.8	2.095	2.738	4.587
(κ_e)	2	0.6	1.457	2.413	4.729
Value added	1	0.6	0.781	1.018	1.688
(α_{oe})	2	0.3	0.515	0.868	1.709
Profits	1	0.3	0.357	0.473	0.838
(ζ_e)	2	0.2	0.321	0.494	0.946
Value added (investment	1	0.333	0.373	0.372	0.368
criterion (α_{oe}/κ_e)	2	0.500	0.354	0.360	0.361
Profits/investment	1	0.167	0.170	0.173	0.183
criterion (ζ_e/κ_e)	2	0.333	0.220	0.205	0.200

output method therefore lies in the different treatment of internationally traded intermediate (and capital) inputs. In an open economy with foreign trade in intermediate inputs, the production effects of the usual input-output type will depend on the extent to which intermediate goods are produced domestically. If all intermediate inputs are imported, no production effects on other sectors occur and the inverted Leontief matrix simply becomes a unit matrix. If, on the other hand, all intermediate goods are produced domestically, maximum production effects on all sectors of the economy which are technologically linked with one another occur, as measured by the Leontief inverse based on technical input-output coefficients. If, in an open developing economy with a limited industrial base and a variety of imported intermediate products, new productive activities are established, the estimation of the expected domestic production effects with traditional input-output techniques becomes problematical.

The problem of estimating direct and indirect production effects becomes even more complicated if resource allocation considerations deriving from the theory of comparative advantages are introduced. These considerations will indicate the desirability of specialization in the production of a limited number of intermediate products and they dictate against the development of domestic production of other products which can better be supplied from abroad, because of their unfavourable

factor proportions at the prevailing relative scarcities. It is exactly the recognition of 'the fact that there is never a technical necessity to combine one international-industry project with another' [15, p. 121], which makes the semi-input-output method differ from traditional input-output analysis.

Once the complementary effects of a capacity expansion in an international sector are established and valued, sectors can be ranked according to their attractiveness for a given criterion. Formally, such criteria can be derived by formulating the semi-input-output method as a programming model. Depending on the choice of the objective function and the specified constraints, the various selection criteria follow from the dual solution.[5] As the numerical example shows, changes in value of the direct criterion, on the one hand, and of the bunch and total criteria on the other hand, are such that a reversal in the ranking of the international sectors occurs.

The estimation of bunch effects is considerably affected by *trade imperfections and distortions.* Because the latter imply restrictions on export and import demand, but not on *domestic* demand, the behaviour of such a "domestically producing" international sector may become identical with that of a national sector, and the corresponding balance equation can be transferred from eq. (4) to eq. (5). Thus, the complementary bunches of investment will change in size and composition when trade restrictions become binding. As a result, the attractiveness of sectoral capacity expansions is affected and changes in the ranking of the international sectors according to a criterion of attractiveness may occur. In particular the attractiveness of those international sectors having strong linkages with the 'domestically producing' international sector can be expected to change, because production expansion in those sectors will induce domestic demand for the products of the export-restricted sector. The extent to which significant rank reversals are likely to occur in reality remains an empirical matter; a full assessment of the importance of trade limitations in the context of semi-input-output analysis cannot be made without reference to empirical results.

V. APPLICATIONS AT THE PROJECT STAGE

Whereas at the sector level the choice of sectors to be developed and the volume of sectoral expansions are equally important, such questions are of quite a different nature at the project stage. For a large number of projects, their size is often dictated by technical and market conditions; when the question of different project size arises, the number of alternatives is usually limited. Except for those cases where economies of scale play an important role, project appraisal usually refers to different projects of a given size or to project alternatives of the same size when technical choice is considered. For a given selection criterion, projects or

[5] One of the criteria so derived can be shown to reflect the well-known domestic resource cost criterion.

project alternatives are either accepted or rejected. As the cut-off rate for accepting a project is not always easy to determine, a ranking of projects according to a criterion of attractiveness is sometimes presented. The proper estimation of project effects, their valuation as benefits and costs, and the final selection of projects can therefore be considered the main elements of project planning.

Generally, project effects can be identified by comparing estimated changes in the economy caused by a particular project with alternative changes that would have occurred without the proposed project. As explained in the preceding sections, among such effects are the direct effects – the physical inputs and outputs – and indirect effects – the necessary capacity adjustments on the supply side in those vertically related stages of production for which no alternative source of supply exists, i.e. the national industries – together making up the bunch effects of a project.

Because a project can be considered the smallest technically independent unit of production, the identification of effects of a capacity expansion at the project stage differs from that at the sector stage in a number of respects. At the project level, the life-time of capacity expansions is explicitly taken into account. Partly related to it is the explicit distinction between the investment or construction period and the operation period, implying the calculation of two kinds of project effects: one referring to investment activities and the other to operating or current activities. In many cases, first-order and sometimes higher-order capital inputs, current inputs, and outputs are project-specific, and can therefore only be properly identified at the micro level. Direct substitution through the choice of techniques can only be realised through the implementation of new projects. The project stage is therefore particularly suited for the identification of alternative techniques.

Under a number of simplifying assumptions, the composition of complementary bunches for project effects can be derived in a way similar to that at the sector level. There are, however, some interesting differences. At the project level, the explicit distinction between the construction and operation period implies a corresponding distinction between the complementary indirect effects. This distinction is especially relevant with respect to the length of the operation period. The definition of direct capital and current input requirements as project-specific permits a distinction between international *sectors* and *commodities* as well as the identification of different techniques to produce a specific good.

Apart from the identification of project effects, the semi-input-output method has particular relevance for the *valuation* of effects, notably the estimation of accounting prices for *national, non-tradeable products.* Assuming that (i) sufficient input-output data expressed in terms of producer's prices are available, and (ii) international goods are valued at the domestic currency equivalent of their border value in order to reflect world market conditions, the following simple price model for the determination of accounting prices for national goods can be formulated.

$$p_F' = u_F' \, (I_{FF} + \hat{\tau}_f)^{-1} \qquad \ldots \qquad \ldots \qquad \ldots (11)$$

$$p_F' = p_F' \, A^*_{FF} + p_D' \, A^*_{DF} + \lambda w_F' + (p_F' \, K^*_{FF} + p_D' \, K^*_{DF}) \, \hat{P}_F \qquad \ldots (12)$$

$$p_D' = p_F' \, A^*_{FD} + p_D' \, A^*_{DD} + \lambda w_D' + (p_F' \, K^*_{FD} + p_D' \, K^*_{DD}) \, \hat{P}_D \qquad \ldots (13)$$

where, in addition to the symbols defined,

p_N	=	vector of N commodity accounting prices, partitioned into sub-vectors p_F and p_D,
τ_F	=	vector of nominal *ad valorem* tariff or tariff-equivalent rates on F international goods,
w_N	=	vector of sectoral unit labour cost coefficients, partitioned,
λ	=	accounting wage rate, and
P_N	=	vector of sectoral accounting values for capital recovery rates, partitioned.

Asterisks (*) indicate coefficients which are measured in the unity prices of the initial input-output data (in which volume units have been redefined in such a way that all commodity market prices equal unity). Consequently, the elements of matrices A^*_{NN} and K^*_{NN} assume the same value when measured in volume and value units. A hat (ˆ) converts a vector into its corresponding diagonal matrix.

Eq. (11) shows that the border price of international goods is computed from the domestic producer's price by correcting for the import (export) tariff or tariff-equivalent. In the absence of trade distortions, the accounting price for international goods is therefore simply one; when subject to import (export) tariffs, the accounting price is less (more) than one. Alternatively, accounting prices for international goods could have been determined by correcting the relevant c.i.f. or f.o.b. border price in domestic currency for transport and trade margins at accounting prices. Eqs. (12) and (13) are conventional input-output price-fix equations saying that the accounting price of a commodity can be built up from the various cost components per unit of output valued at accounting prices. Labour costs are measured using a uniform accounting wage rate for all sectors. Capital costs reflect services of the various capital goods required for the production of a particular commodity; they are measured using sectoral capital recovery rates which are applied indiscriminately to all types of capital goods within one sector.

Formulated in this way, the price model has D + 1 degrees of freedom, necessitating additional assumptions to obtain a determinate solution. First, equalization of the rate of return to capital in the national sectors can be assumed by implication according to the following D − 1 independent conditions:

$$\hat{\mathsf{P}}_D = \mathsf{P}\, I_{DD} \quad \ldots \quad (14)$$

As the accounting prices for international goods follow directly from eq. (11), or from an alternative approach, they can be considered independent of the rest of the model. Prices for national goods can be found by solving eq. (13) in terms of p_F and the remaining unknowns λ and **P** giving:

$$p'_D = (p'_F \, H^*_{FD} + \lambda w'_D)\,(I_{DD} - H^*_{DD})^{-1} \quad \ldots \quad (15)$$

where matrix $H^*_{NN} = A^*_{NN} + \mathsf{P}K^*_{NN}$.[6] Price eq. (15) now expresses the accounting price of the national goods as the sum of the semi-cumulative (direct and indirect) unit cost of international goods at border prices and of labour valued at the accounting wage. In both expressions allowance has been made for the cost of using capital services in production. Characteristically, indirect costs refer to national products only. Eq. (15) can be solved once the accounting wage rate λ and capital recovery rate **P** are known. The vector of (non-uniform) capital recovery rates in the international sectors P_F follows residually from eq. (12). When the price model is closed with respect to the non-tradeable primary factor labour, and the rate of return to capital as implied by the value of the capital recovery factor **P** equals the accounting rate of interest (ARI), the model coincides with the Little-Mirrlees method of calculating accounting prices for non-tradeable goods: their price can be expressed in terms of tradeables and labour.

When no data on the distribution of value added are available, the expressions for labour and capital costs in eqs. (12) and (13) can be replaced by a general expression for sectoral value added $\pi'_{oN}\hat{\alpha}^*_{oN}$. Vector π_{oN} acts as a vector of price indices with respect to value added (when commodities are measured in market prices the elements $\pi_{oj} = 1$), and is closely related to measures of effective protection. In this case, D additional assumptions must be made to obtain a solution for the accounting prices of national goods.[7]

[6] When new investment is concentrated in one year and annual net benefits are constant during the operation period, **P** and h can, under certain assumptions, be shown to be identical concepts.

[7] The alternative ways of dealing with non-tradeable goods in the theory of protection and their relation to the semi-input-output method are discussed in ten Kate [5].

Selection of Projects

To illustrate the actual *selection* of projects, the data of the preceding section will be used. For the sake of convenience it is assumed that (1) investment costs are concentrated in one year, (2) annual net benefits are constant during the operation period, and (3) all capacity expansions have an equal life-time. Consequently, the selection criteria can simply be formulated as annual net benefits/investment cost ratios. First, the attractiveness of a project in international sectors 1 and 2 will be considered at *market* prices (Table 2).

The national or social gain of projects in sectors 1 and 2 can be thought to be measured by the value added criterion indicating the project's contribution to national income. Value added coincides with social income under well-known conditions: accounting prices for commodities equal market prices and for primary factors other than capital equal zero (implying, among other things, that the full wage bill is eliminated as a cost). The direct profit criterion measures the private gain of a project following traditional financial analysis: outputs, commodity inputs, and primary factors other than capital are valued at their actual market prices. Under another set of well-known conditions, the profit criterion measures the gain to society: all profits are reinvested, wages are fully consumed, and no value is attached to extra consumption. A comparison of the values for the different criteria in Table 2 shows that the ranking, and hence the selection of projects depends on the criterion used. As a result, different criteria might entail different investment programmes.

Table 2

Project Appraisal at Market Prices

Project in sector	Project effects per unit of output: Annual benefits: Value added (α^*_{oj})	Pro-fits (ζ^*_j)	Costs: Investment ($\aleph^*_j$)	Selection criteria: Direct: Value added ($\alpha^*_{oj}/\aleph^*_j$)	Direct: Profits ($\zeta^*_j/\aleph^*_j$)	Bunch: Value added ($\tilde{\alpha}^*_{oj}/\tilde{\aleph}^*_j$)	Bunch: Profits ($\tilde{\zeta}^*_j/\tilde{\aleph}^*_j$)	Valuation: Commodity prices (p_j)
1	0.6	0.3	1.8	0.333	0.167	0.373	0.170	1.0
2	0.3	0.2	0.6	0.500	0.333	0.354	0.218	1.0
3	0.6	0.4	3.0	0.200	0.133	–	–	1.0
4	0.4	0.1	0.4	1.000	0.250	–	–	1.0

Table 3 shows the effect on annual benefits, costs and selection criteria when *accounting* instead of market prices are used. The system of accounting prices is based on the price model presented above. All project effects have been revalued at accounting prices and are indicated by symbols without asterisks.

Table 3

Project Appraisal at Accounting Prices

Project in sector	Annual benefits	Costs	Selection criteria		Valuation
	Social profit (ζ_j)	Investment ($\aleph_j$)	Direct ($\zeta_j/\aleph_j$)	Bunch ($\tilde{\zeta}_j/\tilde{\aleph}_j$)	Commodity price (p_j)
1	0.3977	1.417	0.281	0.262	0.8
2	0.0480	0.630	0.076	0.120	0.6
3	0.4145	0.764	0.150	–	0.716
4	0.0522	0.348	0.150	–	0.689

$\tau_1 = 0.250, \tau_2 = 0.667, \lambda = 0.680, P = h = 0.150$

Because the wage bill valued at accounting prices is now considered a social cost, benefits represent social profit rather than social income in the terminology of Little-Mirrlees. It is therefore interesting to compare the analysis of projects 1 and 2 in terms of social profits in Table 3 with the financial analysis in terms of private profits in Table 2. Not only do benefits and costs differ considerably, the ranking of projects 1 and 2 is different too and an altogether different investment programme is likely to result.

Some interesting consequences with respect to the selection of projects arise when rate of return equalization in the national sectors is imposed, and the corresponding value equals the (cut-off) accounting rate of interest.[8] In this case the selection of projects becomes independent of linkages between international and national sectors, because the bunch criterion for a project in an international sector is simply a weighted average of its direct criterion and the ARI (which applies to all national sectors). Once the direct criterion valued at this particular set of accounting prices of a project exceeds (falls short of) the ARI, the corresponding bunch criterion also exceeds (falls short of) the ARI and projects can be appraised in isolation, as is the rule in conventional project analysis. Rank reversals may still occur, but only within the two subgroups of projects with direct criteria above or below the cut-off

[8] I am indebted to Dr. P.G. Hare for suggesting some of the implications with regard to the Little-Mirrlees method.

rate (see Table 3 where the ARI equalization assumption shows up in a cut-off capital recovery rate P = 0.15).

Summarizing, the following conclusions can be drawn from the examples presented above. Rank reversals which occur when using *bunch* instead of *direct* criteria illustrate the importance of indirect effects for the appraisal and selection of projects. Rank reversals which occur when using *accounting* instead of *market* prices emphasize the significance for a project's attractiveness relative to that of others, and hence for its selection. Given the various methods of determining accounting prices, the use of bunch selection criteria becomes mandatory where the derivation of a particular set of accounting prices does not assume an equalization of the rate of return to capital in the national sectors to the accounting rate of interest. When such an equalization is assumed, as in the Little-Mirrlees method, there is no need to calculate complementary indirect effects as far as the selection of projects is concerned.[9]

VI. EMPIRICAL APPLICATIONS TO NIGERIA

In a case study for Nigeria, the semi-input-output method has been applied empirically to 106 sectors: 4 primary sectors, 50 existing manufacturing sub-sectors, 48 new manufacturing activities, mainly on a commodity basis and derived from project data, and 4 national sectors. Data on the manufacturing sub-sectors are partly available on the basis of the annual *Industrial Survey of Nigeria,* other data are obtained from national accounts and updated input-output statistics. On the whole, the estimated parameters can be thought to reflect the prevailing economic situation in Nigeria in the early 1970's.

The empirical application has special relevance for two problems discussed earlier: (a) the effect of trade limitations on the selection of sectors and projects, and (b) the different effect of using market and accounting prices on investment appraisal. The basic framework for the application of the method is the model described in section 3 and its extensions in the two subsequent sections; in addition, the following refinements are added.

1. Imports are differentiated into competitive and non-competitive imports.
2. Capital investment is differentiated into fixed capital formation and changes in working capital to finance inventories of different kinds (raw materials, semi-finished, and finished products).
3. Annual benefits are expressed alternatively as value added (market value of outputs minus non-primary inputs), social income (accounting value of outputs minus non-primary inputs), net profits (value added minus the sum of the market value of labour cost and depreciation), and net social

[9] A different interpretation of the correspondence between semi-input-output and Little-Mirrlees has recently been proposed by Bell and Devarajan [2].

profits (social income minus the sum of the accounting value of labour cost and depreciation).

4. Selection criteria to appraise the attractiveness of a capacity expansion in an existing or new sector relate annual benefits to the total capital investment (see Tables 2 and 3).
5. For the 50 existing manufacturing sub-sectors, annual benefits are expressed in terms of net (social) profits and value added (social income). Due to lack of data on the distribution of value added over labour and non-labour components, annual benefits for the 48 new activities, the 4 primary sectors and the 4 national sectors are in terms of value added (social income) only.
6. When a trade restriction is imposed on the best international sector in the absence of trade limitations (first run), this sector becomes a "domestically producing" international sector and is added to the 4 national sectors. The bunch value added criterion for the remaining 101 international sectors is computed again with 6 sectors included in the bunch: 1 out of the 101 remaining international sectors, 4 national sectors, and 1 "domestically producing" international sector (second run). The ranking of the unrestricted international sectors after the first and second runs can now be compared to find out whether the ranking of one or more sectors has improved as a result of restricting trade opportunities for the best international sector in the first run. The same procedure can be repeated for the third and subsequent runs until a maximum of 102 (= F) runs is reached.
7. For the purpose of investment appraisal at accounting prices, all structural coefficients, derived from data expressed in actual market prices, must be revalued at accounting prices. This requires the estimation of relevant accounting price ratios (ratio of accounting to market prices) for commodities and primary factors of production. A summary of the estimated accounting price ratios is included in Table 4.

The aggregate rate of effective protection for the Nigerian economy amounts to about 5 percent, which, by assumption, is imposed on the national sectors ((1.00 − 0.95)/1.00 = 0.05). This figure appears reasonable for an economy dominated by unprotected primary activities. As a result, the effective rate of protection of these activities is therefore slightly negative. In contrast, the average figures for the 50 existing manufacturing sectors show that on the whole manufacturing appears heavily protected. For an estimated average nominal protective rate of 65 percent, the average effective rate of protection equals 52 percent according to the U-measure, i.e., 108 percent according to the Z-measure.[10] The way in which the 48 new activities are assumed to be recorded implies that those activities using domestically produced intermediate inputs are negatively protected.

[10] $1.00/1.65 \cong 0.60; (1.00-0.48)1.00 \cong 0.52; (1.00-0.48)/0.48 \cong 1.08.$

Table 4

Selected Accounting Price Ratios, Nigeria, early 1970s

Title	Commodities, primary factors	Value added
Primary sectors (average of 4)	1.00	1.02
Manufacturing sub-sectors (average of 50)	0.60	0.48
New activities in manufacturing (average of 48)	1.00	–
National sectors (average of 4)	0.92	0.95
Non-competitive imports	1.00 or 0.70	–
Labour	0.50	–
Land	0.90	–

VII. RESULTS

Some of the results of the computations for the 50 existing manufacturing sub-sectors, the 4 primary sectors and the 48 new industrial activities are summarized below.[11]

Analysis of 50 Existing Manufacturing Sub-sectors at Market Prices

For the existing manufacturing sectors three different criteria of attractiveness are applied: direct net profit, direct value added, and bunch value added to capital. A comparison of the sector rankings according to the three different criteria shows in several cases interesting changes in a sector's order of rank, although the Spearman rank correlation coefficient between the different rankings is fairly high: 0.8963 between the direct net profit and direct value added criterion and 0.9621 between the direct and bunch value added criterion.[12] As to the profitability of the manufacturing sub-sectors, for a cut-off rate of net profit to capital of 15%, 13 out of 50 sectors are sub-marginal; for a cut-off rate of 20% the number of sub-marginal sectors increases to 23.

Analysis of all 102 International Sectors at Market Prices and Under Trade Restrictions

Because of data limitations only value added criteria are used. As 3 of the 4 primary activities (agriculture; livestock and forestry; fishing; oil mining) are highly

[11] For a more detailed analysis, see Kuyvenhoven [7, Chap. 7] and [8].

[12] As the different criteria of attractiveness employed do not necessarily imply a complete reversal of the sectors' attractiveness, relatively high values for the Spearman rank correlation coefficient need not be surprising. This applies in particular to the difference in ranking between direct and bunch criteria, because only 4 national sectors are distinguished.

attractive, substantial changes in the attractiveness of other international sectors occur when trade restrictions are imposed on the three primary sectors. This is particularly true of the agricultural sector, which is a major supplier of a veriety of inputs to some 25 processing industries. Thus, when a trade restriction is imposed on the agricultural sector, so that it becomes a "domestically producing" international sector and is added the bunch of national and other domestically producing sectors, almost all food, beverages, tobacco and other agro-processing industries show marked increases in their attractiveness. Insofar as the favourable attractiveness of the agricultural sector reflects the local availability of relatively cheap raw materials for which export possibilities are limited, the inclusion of the agricultural sector in the bunch improves the expalanatory value of the semi-input-output method considerably. The Spearman rank correlation coefficient, being 0.9809 between the direct and bunch value added criterion, decreases to 0.9206 after agriculture is included in the bunch.

Analysis of 50 Existing Manufacturing Sub-sectors at Accounting Prices

In addition to the three criteria net social profit, direct social income and bunch social income to capital, implied rates of effective protection are obtained. Both nominal and effective protection appears to vary widely among the manufacturing sub-sectors, and a comparison with the results at market prices shows a number of interesting differences. First, for a large number of sectors the relative attractiveness at accounting prices increases (decreases) substantially because of a low (high) degree of protection on value added at market prices (the Spearman rank correlation coefficients between net profitability and net social profitability, direct value added and direct social income, and bunch value added and bunch social income are 0.5581, 0.5352, and 0.6143, respectively). Second, differences in a sector's order of rank as between different criteria of attractiveness are more pronounced at market than at accounting prices (the Spearman rank correlation coefficients between net social profit and direct social income, and between direct and bunch social income are 0.9801, and 0.9885, respectively). Third, the high level of protection in manufacturing can be illustrated by the high number of sub-marginal sectors at accounting prices: roughly twice as much as the number at market prices when a cut-off rate of 15% is used; the difference refers in particular to consumer goods and building materials industries. Fourth, a number of labour-intensive industries which are sub-marginal at market prices are *not* so at accounting prices.

Analysis of all 102 International Sectors at Accounting Prices

Similar differences as in the case of the 50 manufacturing sub-sectors are observed when the analysis is extended to all sectors. Almost all 48 new manufacturing activities and the 4 primary sectors show an increase in relative attractiveness when measured in accounting instead of market prices, a result consistent with the negative rates of effective protection recorded for those sectors. As to the behaviour of sub-marginal sectors, at market prices 13 out of 50 existing manufacturing sub-sectors and 24 out of 48 new industrial activities can be considered sub-marginal. At accounting prices, however, 26 out of 50 existing and 17 out of 48 new activities in manufacturing appear sub-marginal. This difference for new activities clearly illustrates the effect of appraising unprotected new projects using domestic inputs produced under protection.

The outcome of this case study bears direct relevance to the Nigerian economy. It confirms that a large number of manufacturing sub-sectors are heavily protected and not competitive with imports. This applies in particular to various consumer goods industries. Many intermediate and mechanical goods industries, however, appear fairly attractive, justifying a further diversification of the consumer-goods-dominated Nigerian manufacturing sector. Because rates of protection vary considerably among manufacturing sub-sectors, and primary activities as well as several processing industries using local raw materials are not protected or negatively protected, a sector's attractiveness at market prices has, in many cases, little to do with the actual benefits and costs to society. In such a situation, investment appraisal at accounting prices becomes indispensable for a proper allocation of resources.

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