CHAPTER IV

ENERGY MODELING IN INPUT - OUTPUT FRAMEWORK

4.0 INTRODUCTION

Many Energy-Economy models and methodologies appeared in the scene after the first energy crisis as is evident from the last chapter. In this chapter, the concentration is on the methodologies seems relevant to the present study.

(1) Input-Output multipliers and coefficients,
(2) Linear programming Input-Output (LP-IO)

The purpose of this chapter is to describe the nature, structure and the uses of these models in energy-economy analysis of the energy demand in India. As explained in the introductory chapter their different perspective and uses provide important information to energy policy makers.

In section 4.1, a review of literature on Input-Output analysis has been undertaken. Section 4.2, traces the conception, development and the implementation of Input-Output tables in the Indian planning process. In Section 4.3, the Leontief interindustry model is described. Within this framework, input-output multipliers and coefficient of various types are defined. While doing so careful consideration is then given to energy-economic final demand coefficients as the most appropriate indicators for investigating trade-offs between economic development and energy use on the sectoral level analysis.The fourth section 4.4, integrates the input-output models with optimizing techniques for the macro level analysis. The uses of

LP-10 are introduced and their role in energy planning is evaluated.

Any 'institution' in an organized society in 'process' undergoes change. The 'economic institution' in its broadest term, transformed itself from the primitive, self-contained mode of production to more elaborate process, leading to specialization and exchange. Such transformation calls for an investigation into the interwoveness of economic interdependence both in its theoretical and empirical aspects.

In the realm of pure theory, theorizing the dynamics of production structure began more than two centuries ago with the construction of Tableau Economy(1766)[1] by the famous French Economist Francios Quesney and culminated in the work of Leon Walras (1874).[2] The Walrasian General equilibrium models, at best, a brilliant show piece of economic theorizing. Besides this, the elaborate model involving thousands of behavioral and technological relations were considered to be empirically unmanageable. On the other hand, Grand System of Economics so assiduously developed and reflected by a galaxy of brilliant Neo-Classical economists was being exposed as the assumption of 'other things remaining the same' became more and more tenuous during the twenties"[3]. These partial models, suitable for analyzing the impact of small disturbance within a delimited system of an economy, were deemed to be amusingly naive to be useful in the thirties.

On the other hand, disillusioned by the practical inapplicability of theoretical economics for analyzing or predicting economic reality, Scholars and others of Historical school filled volumes with their empirical findings, essentially similar empiricist school of statistical economist led by the National Bureau of Economic Research, USA, filled volumes with figures alas devoid of words.

Looking at this state of affairs, Leontief exclaimed. "Why is it that despite such prodigious accumulation building material, the edifice which we are supposed to be erecting still seems to be in a stage of preliminary excavations?"[4] He boldly chalked out a practical program aimed at the fusion of the two through which, "The statistical data collected fill in the empty boxes of the theory as soon as the symbolic algebraic signs are replaced by observed numerical values. Once an empirical foundation is thus established, the value generalities of abstract theoretical statements will acquire concrete empirical significance"[4]. Thus, born the I-O framework. His input output and Economic analyses fuse theoretical clarity, mathematical manipulation and statistical fact into a tool of practical power, with the simple and powerful use of matrix algebra in Economics.

The dynamics of input - output analysis is to verify the proposed or assumed economic growth so that the final demand would be consistent with the quantity available of some primary resources.[5] The primary resources are not used in isolation in the production process rather it enters into a chain reaction as the demand for final users set in motion activities among industries directly or indirectly. It was a case of chemical industry that Tarabucchi, c et.[6] al used the input - output technique to determine the valid correlation between industry and all sectors of the economy and to develop a consistent and coherent system by which direct or indirect exogenous effect on every single product can rapidly be measured not only for the past but mainly for the future. Like wise,

Since Leontief's initial work in the 1930's many presentations of input output models have appeared in the literature. (Bills and Barr, 1968; Carter, 1974; Chereney and Clack, 1965; Ching, 1981; Dorfman et al., 1958; Fisher, 1958; Harris and Ching, 1982; Lee et al., 1976; Lieu, 1977, 1980; Malinraud, 1954; O'Malley, 1973; O'Connor and Henry 1975; Pach, 1982; Penn and P.N. Mathur, 1976; Irwin, 1977; Rasmussen, 1957; Richardson, 1972; Sapir, 1976; Yan, 1969; Leontief 1986; Ciaschini, 1988; Miller, Polenske and Rose, 1989; Peet, 1993). It would be of interesting and a rewarding experience to read the original work containing a collection of papers by Leontief himself. A very lucid and concise presentation of the input - output technique can be found in the work of Amitab Kundu and Saluja.

4.1 Development and Uses of I - O Tables in India

The first official Input - Output table was compiled by the Central Statistical Organization (CSO) in collaboration with the Perspective Planning Division (PPD), Planning Commission for the year 19668 - 69. The 1968 - 69 table was also the first attempt to confirm to the Systems National Accounts (SNA) of the United Nations. Since than the Central statistical Organization compiles I - O tables every five years The CSO has released the I - O tables for 1968 - 69, 1973 -74, 1978 - 79, 1984 - 85.

When the CSO first brought out the Input-Output table, it was more detailed, encompassing 225 sectors of the economy. But then, for 1973-74, the entire economy was divided into 115 sectors covering (I) primary products, (ii) manufacturing (iii) tertiary sectors. In the table, the first 32 sectors dealt with the primary production, the next 66 sectors covered the manufacturing sectors and the remaining 17 sectors dealt with the tertiary sectors. The level of disaggregation adopted for classification of industries generally corresponded to 3 digits level of National Industrial Classification for 1970. For 1978 - 79, CSO maintained the same sectoral classification as was the case in 1973 - 74, except that the electrical machinery sector was further bisected into electrical and electronic equipment as the latter played a greater role in terms of value added and growth.

4.2.2 Input - Output Methodology followed in India:

The Indian input output tables of 1973-74 and 1978-79 were tabulated in the conventional format, following the pattern adopted in Great Briton. The input output table consisted of a transaction table and an import matrix. These two matrix form the basis for obtaining a domestic transaction table. The tables were calibrated with SNA of the United Nations. They include a make matrix (industry x commodity and an obsorption matrix(commodity x industry) among other associated table, both of which would give the combined conventional transaction table (commodity x commodity). The year 1984-85 was adopted as a base for the purpose of projections for the Seventh Five Year Plan, 1985-90. For this purpose the input output table for 1984-85 was constructed based on the CSO table for 1973-74. This table was adopted and updated and aggregated to 50 sectors for the construction of input output table during the year 1984-85. The coefficients were converted to 1984-85 prices so that the basic input output relations remained consistent with the price level corresponding to final demands which were independently estimated at 1984-85 prices. Adjustments were made to derive the intermediate using the final demand in each sector and subtracting it from the gross output levels. A balanced input flow matrix for 1984-85 was finally obtained on the basis of RAS method using the row and column control tables.

The second basic component of input output table integrates the import matrix, which is being divided into two parts. The first is the 50 X 50 technological matrix indicating the amount of import used as current input in production and the second corresponds to the final use of sectors which is being satisfied through imports. The two parts of the import matrices relating to interindustry use were obtained by allocating the import of each sector to the relevant import cells and final uses of the balanced input output table for the year 1984-85 at market prices.

For the purpose of this study the 1989-90 input output table is being utilized, the latest I-O table available.[6] While the I-O table for the year had 50 sectors, the 1989-90 table has 60 sectors. In order to make the table comparable, they were adjusted into uniform sectoral classification of 24 sectors as shown in the energy intensity table in the previous chapter.

In general, input-output table is an accounting framework for assembling data on industry inputs and outputs with several interrelated transactions occurring in a modern economy. The important feature of this accounting framework is that it provides a framework within which the complex of intra-industry transactions generated in a modern economy can be handled with relative ease. The central principle is that every transaction is both a sale and a purchase, the value at the point of transaction being the same in both the cases. To avoid recording such transactions twice, input output tables employ a cellular array system leading to sets of tables, called matrices, in which sales are represented in the rows and purchases in the columns, it represents both aspects of each transaction leading to economy and clarity of presentation.

4.3 Leontief Interindustry Model

A simple Leontief system can be expressed in terms of a set of simultaneous linear equations:

$$X_i = \sum x_{ij} + c_i \quad (i = 1,2, \ldots n) \text{ ------- } (1)$$
$$(j = 1,2,3 \ldots n)$$

where : X_i = gross output in the industry

X_{ij} = output of industry X used as input in the jth industry

C_i = output of industry I available for outside consumption or Final demand.

Equation system (1) known is the balance equation, says that the total gross output of a commodity is equal to interindustrial requirement and final consumption demand, which may comprise of private and public (Govt.) consumption, capital formation, and net foreign trade*. The Equation system (1) can be presented in a tabular form in the line of input output scheme as follows:

Table 4.1
Input Output transactions matrix

	1		2	3--- n	C	Output
1	X_{11}	+	X_{12}	+ X_{13} ... X_{1n}	+ C_1 =	X_1
2	X_{21}	+	X_{22}	+ X_{23} ... X_{2n}	+ C_2 =	X_2
3	X_{31}	+	X_{32}	+ X_{33} ... X_{3n}	+ C_3 =	X_3
	--		--	-- --		
n	X_{n1}	+	X_{n2}	+ X_{n3} ... X_{nn}	+ C_n =	X_n

The central feature of the input output analysis is the technology of the economy, assumed to be given and expressed in the form of a production function. The analysis however, is made under certain simplifying assumptions. In a general formulation, there are in n industries and n commodities, each of which is produced by just one industry but used as an intermediate product by number of industries. Production takes place through "Process" and no apparent substitution in each industry. The given process can be denoted as:

$$X_{ij} = a_{ij} X_i \quad (i,j = 1, 2, \ldots n) \quad \ldots\ldots\ldots\ldots(1)$$

where
a_{ij} = the amount of ith good used to produce a unit of jth product i.e. input coefficient

we can rewrite the system of equation (1) as:

$$X_i = \sum a_{ij} X_j + C_i \quad (i = 1, 2, \ldots n) \quad \ldots\ldots\ldots\ldots (2)$$

$$(j = 1, 2, \ldots\ldots\ldots\ldots n)$$

Equation system (2) constitutes the fundamental relationship of a simple Leontief system. The input output relations are thus of the simplest form - linear relations of direct proportionality, In fact, in a very special case of the more several methods of linear programming or activity analysis, the "activities" which are programmed are a given set of industrial process. As a result of a given process, it is appropriate to define the production activity for each sector in terms of a set of input/output coefficients:

$$aij = xij/xj \quad \text{------------------------}(3)$$

Thus equation system showing the interdependency of the various sectors may be rewritten as:

$$a_{11}X_1 + a_{12}X_2 + \ldots + a_{1n}X_n + C_1 = X_1$$
$$a_{21}X_1 + a_{22}X_2 + \ldots + a_{2n}X_n + C_2 = X_2$$
$$a_{31}X_1 + a_{32}X_2 + \ldots + a_{3n}X_n + C_3 = X_3$$
---- ----- ---- ---- ---- -----
$$a_{n1}X_1 + a_{n2}X_2 + \ldots + a_{nn}X_n + C_n = X_n$$

The basic relations could then be rewritten compactly in matrix notation as:

$$AX + C = X \quad \text{------------------------}(4)$$

or $$(I-A)X = C \quad \text{------------------------}(5)$$

Where:

X = n x 1 vector of sector outputs
C = n x 1 vector of final demands
A = n x n matrix of technical coefficients
I = n x n identity matrix

* Technical coefficients are sometimes referred to as a production recipe because the column shows the quantity of production or service required from each sector to produce say Rs.1.00 work of output by the sector heading the column.

It is obvious from the equation (4), (5) that once we have matrix (A), the matrix of coefficients and the vector of total output X, we can easily obtain vector C which gives the amount of each commodity available for final use. Similarly when A and C are given we could solve for X, and such a result would be just tautologically for the year for which the input output table is constructed, it would be substantive when we need to compute such an information for some other specified period. This, of course, assumes the technology coefficient matrix (A) to be the same in the two periods.

Since the general purpose of the Leonteif interindustry model is to determine the effects of changes in final demand on the regional economy, one can rearrange the equation system (5) as follows:

$$X = (I-A)^{-1} \; C \quad \text{---------------------(6)}$$

Where

I = n x n identity matrix

This is the basic equation in input output analysis. The matrix, $(I-A)^{-1}$, can then be used to determine the economic effects within the context of interindustry multipliers as discussed in section 4.1.2.

4.4.1 Traditional Economic Multipliers

Within an input output framework, it is possible to derive a set of multipliers, that give summary measure of total repercussions in terms of adjustments in output, employment and income etc., generated by a given change in the final demand vector. The income and employment multipliers of Keynes, the important tools of macro economic analysis, are highly aggregative in nature as they are based on one sector economy. However in the interindustry framework, an initial expenditure on an economic system does not depend merely in its volume of expenditure but on the interindustry and inter regional linkages of the sector with the rest of the economy[7]

In an inter industrial frame of work, the multiplier of any type for a sector may be defined as the ratio of the direct and indirect additions made in response to an initial change of one unit in that sector. The different type of multipliers discussed here are:

(I) the output multiplier: defined as:

$\tilde{A} = j\ (I-A)^{-1}$ where

$\tilde{A}$ = 1 x n vector of output multipliers

j = 1 x n sum vector.

Thus the output or sales multiplier is the column of sums of the matrix $(I-A)^{-1}$.

The output multiplier can be interpreted as: If the final demand of the k^{th} sector were to increase by one unit, the k^{th} output multiplier would indicate the change in output in the whole economy

(ii) Employment multiplier: The following equation defines the employment multiplier:

$N = P\ (I-A)^{-1}$

$\mu i = qi\ /\ Pi$

where

P = 1 x n vector of direct employment Coefficients, i.e., the ratio of total employment to total Sales for each sector: elements of P are Pi, q = 1 x n vector of total direct and indirect changes in employment, elements of q are qi. These are also referred to as employment final demand coefficients.

μi= employment multiplier for that sector.

The employment multiplier, μi, shows the total change in regional employment if the employment in the i^{th} sector increases by one unit.

(iii) The income multiplier: which is defined as:

$Z = W(I-A)^{-1}$

$Yi = Zi/Wi$

where

W = 1 x n vector of direct income coefficients, i.e., the ratio of sectoral income to total sales for each sector; elements of W are Wi.

Z = 1 x n vector of total direct and indirect changes in elements of Z are Zi. (These are also refered to as income final demand coefficients).

Yi = Income multiplier for i^{th} sector. The income multiplier, Yi show the total changes in regional income if income in the i^{th} sector increases by one unit.

4.4.2 Energy Multipliers

Ching and Harris[8] argue that there is no reason to focus only upon usual economic multipliers such as: output, employment and income. We can also appropriately analyze the resource multipliers. In particular, they discussed water multipliers, water-economic final demand coefficients and their application to regional economics. They argue that if one were interested in the effect of energy utilized by the different sectors in the economy, we can apply the same multiplier concept by defining the direct energy coefficients and then utilize the $(I-A)^{-1}$ matrix to compute the desired direct and indirect effects which would then be used in the computation of energy multipliers the energy multiplier is defined as: follows:

$$r = e\,(I-A)^{-1}$$

$$E_i = r_i/e_i$$

where:

e = 1 x n vector of direct energy coefficients, i.e. ratio of total energy, used to total sales for each sector, elements of e are e_i

r = 1 x n vector of total direct and indirect changes in energy use; element of r are r_i. (These are also referred to as energy final-demand coefficients).

E_i = Energy multiplier for i^{th} sector. The energy multiplier, E_i shows the total changes in regional energy use if energy use in the i^{th} sector increases by one unit.

Though this approach is superior to the direct energy coefficient as it account for both direct and indirect effects on the whole economy arising from particular changes within a specific sector. However, the limitation of this approach is that it counts only the cost, i.e. energy consumption, while the value added is excluded from models function. Any policy prescription based purely on the energy multiplier may lead to constraining a particular sector which requires significant energy input. For example, if the textile industry is classified as more energy use industry, the policy makers might decide to constrain the expansion of this sector to reduce the total energy consumption. However, they have to reevaluate their policy if the value added of the textile sector is to be taken into account.

For this purpose Harris and Ching[9] further extended the idea of interindustry multipliers to examine the trade-offs between energy use and economic entities. One such multiplier in the energy-income final demand coefficients which estimates the trade-offs between energy use and sectoral income within an interindustry contest and can be defined as:

$$Ti = ri/zi$$

where

Ti = 1 x n vector of energy income final demand coefficients which reflects the total (direct plus indirect change in energy use per unit total change in income, bought by sector i.

In this study the energy income final demand coefficients are adopted as an appropriate measure.

4.5.0 REMARKS ON INPUT OUTPUT MODEL FOR ENERGY ANALYSIS

Input-Output models as described in the earlier section, provide a comprehensive view of the economy at a point in time. This makes it a useful device for answering certain question about how the economy will respond to a particular change in a given sector,: both in detail and in overall, such as, what are the repercussions for all the industries in the economy of an increase in the output of a particular sector, or an increase in the price of an industry's output or an increase in the final demand requirements. This makes the input output analysis a more desirable research tool than the traditional micro and partial equilibrium macro approaches for energy analysis. Energy flows are not concentrated in one sector or industry or firm, as has been assumed in the past. Most energy is consumed not as a final product but as derived demand by sectors in the economy. in fact energy has become an universal input quite similar to the other input, such as capital to all sectors.

Interdependence arising from energy flows is far greater than that had been recognized. Researchers have only recently began to comprehend the complexity of energy transfers and usage throughout the economy. Analysis of the relationship of energy to various component of the economic system requires treatment of those components in the context of the total economic setting of ,which they are a part.[9]

4.6 INPUT OUTPUT ANALYSIS AND PROGRAMMING TECHNIQUE

The energy income final demand coefficients emphasize activities at the micro-sectoral level. This approach is useful when planners are intersected in evaluating the developmental alternatives of the specific sector. It enables the planner while formulating if a given strategy for a specific energy consuming economic activity should be promoted or discouraged minimizing energy consumption and maximizing the sectoral value added are the major concerns. However this alone does not suffice. On the basis of the interindustry coefficients and multipliers alone there is no interacting mechanism among sectors for given amount of resource say, energy. That is, within a given regional economy, given an increase or reduction , one knows potential sector that should be stimulated/discouraged by comparing their energy -economic multipliers and coefficients. But one does not know "to what extent" to what extent the potential sectors would expand /contract, and thus, one cannot design a meaningful allocation scheme to cope with the change in the energy supply for the economy. To circumvent this problem , input output models are often integrated with mathematical programming technique for macro level studies.

4.7. INTERINDUSTRY ANALYSIS AND LINER PROGRAMMING

Many economic planners have recognized that interindustry analysis can be used with in the context of linear programming models. the integration of input output analysis and linear programming technique can provide much information not available from separate application of either technique. the former provides the feasible regional economic production possibilities and the latter enables the analyst choose the optimal production alternatives. Richardson enumerates possibilities of use for linear programing algorithm and input output analysis. He suggests that two models are useful in policy analysis where the interindustry model derives the technical inter relationships between the economic sectors and the linear programming algorithm strives towards a stated objective, like maximizing regional income, final demand or employment subject to a resource constraint such as energy, water or labor availability. On the other hand, Dorfman et, al.[10] argue that interindustry model is really a special case of the linear programming or activity analysis model. The difference lies in considering an economic activity as an industry in the input output framework , where as firm in the activity analysis, but the technique to derive the solution in both cases is the same.

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