INPUT-OUTPUT ENERGY-ECONOMY MODELING FOR INTEGRATED ENERGY PLANNING IN INDIA

By

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CERTIFICATE

It is certified that the thesis entitled, INPUT-OUPUT ENERGY-ECONOMY MODELING FOR ENERGY PLANNING IN INDIA, being submitted by Ms. Uttara Nagchoudhuri for the award of the degree of DOCTOR OF PHILOSOPHY in ELECTRICAL ENGINEERING of the Indian Institute of Technology, Delhi, is a record of the student's own work carried out by her under my supervision and guidance.

The matter in this thesis has not been submitted for the award of any other degree.

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A B S T R A C T

As a developing economy with a rapid rate of industrialization, the Indian economy shows an increasing sectoral interdependence and demands increasingly large share of resources in energy sectors in competition with the other economic sectors, in order to cope with the fast-growing demand for energy. These two features of the Indian economy and its energy sector need to be considered in the process of policy planning and analysis of the energy system of India. In the short i.e., a decade-long history of the analytical energy models in India, most models developed in academic and government institutions have been sectoral energy models dealing with a single energy sector or form. Among the analytical energy models for India, Energy System Models involving several energy resources and interactions among them, and Energy-Economy models highlighting interdependence among energy sub-sectors and other economic sectors, are few and far between. The research work outlined in this thesis aims at closing this gap, at least partially, by developing an Energy-Economy model taking into account the interdependence between energy and other economic sectors.

Among various methodologies used for modeling energy-economy interactions, this study focuses on Leontief's inter-industry (Input-Output) framework. The basic model structure is 'open' with the final demand vector treated as an exogenous variable vector outside the interindustry structure. Taking into account the planning pattern in India in the past, i.e. that of five-year plans, a planning period of ten to fifteen years is considered for most part of this study (medium term). The empirical data in input-output form available for India is in the static form. The static version of the input-output model which excludes explicit consideration of the capital-coefficient matrix is used in this study.

With the help of quantitative analysis using this open, static input-output structure, applications of the input-output methodology in the Indian context for energy forecasting , demand management, optimal resource allocation and characterization of technology are illustrated in various parts of this research report.

In the fist part, the basic interindustry framework and its assumptions are explained. The six-sector energy-economy model is obtained by aggregating the data for 1973-74 available in the form of a Leontief-type input-output structure with sixty-six sectors. The six broad sectoral categories are coal, crude oil and petroleum products, electricity, agriculture, transport and industry. The input-output equations representing economic equilibrium of such a structure are given in this part.

For most forecasting applications of static input-output models, an assumption of constancy of the I/O coefficients for a decade is made. In the second part, the errors in the forecasts of energy sectors, due to this assumption of constancy of I/O coefficients, are estimated for the duration of five and eleven years. A simple correction method for updating the I/O coefficients based on price-indices is suggested and tested empirically. Forecasts of output levels using the updated coefficients indicate improvement for the first time period of five years, when disparity in price-changes between sectors is not very large.

In an 'open' interindustry model, for meeting the sectoral final demands optimally, subject to various constraints, an optimization criterion is used to 'close' the model. In this case the I/O model is interfaced with the mathematical model of Linear Programming for optimization of resources. Treating I/O coefficients as variables, their optimal values are computed so as to fulfil a set of technological, energy and equilibrium constraints. For a longer time horizon, the nonlinearities of technologies are approximated by piecewise linear technologies, using multiperiod L.P. model for an optimal resource allocation in 2000-01 A.D.

Application of the same methodology is shown for demand management with the given technological structure and resource limits. This would be pertinent to India as well as many resource-constrained developing countries.

In the last part of the presentation, the input-output structure is represented by a set of non-linear state-space equations. An algorithm, commonly used in control and communication theory, called the Kalman filtering algorithm, is used for estimation of the sectoral gross outputs recursively. In the next subsection, this filtering algorithm is used for estimating technology coefficients (I/O coefficients) recursively, given total gross outputs and final demands of the sectors.

The concluding chapter assesses the contributions of this research work, and points out certain limitations arising due to the model structure in its current form and the present data availability. Some suggestions for further work with minor modifications in the existing structure and some others with more demanding structural changes and data requirements are also made.

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