MODELLING ENERGY-ECONOMY INTERACTIONS IN SMALL DEVELOPING COUNTRIES: A CASE STUDY OF SRI LANKA*

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Charles R. Blitzer and Richard S. Eckaus

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Abstract

This report is addressed at modelling energy-economy interactions in small developing countries, those with populations less than 20 million or so and where neither the industrial or energy sectors are dominant. The overall objectives of the research were to learn more about how energy-economy interactions can be usefully modelled for policy purposes, to compare the pros and cons of alternative methods which have been used previously, and to test the feasibility of utilizing simple general equilibrium models by constructing an illustrative model for Sri Lanka.

Various approaches to energy policy analysis--project evaluation, technology assessment, energy sector assessment, macro simulation models, economy-wide optimization models, and computable general equilibrium models--are surveyed and critically reviewed. A major deficiency of all but the latter two is their failure to account for the important two-way interactions between energy and the rest of the economy which are common in developing countries.

The latter models are general in scope and can include the important energy-economy relationships. Since the computable general equilibrium models are somewhat easier to formulate and solve, they seem most appropriate for the type of countries under consideration. These types of models can analyze a large number of interrelated issues such as: the impact of energy costs and prices on aggregate growth and its sectoral composition; the relationship between energy imports, investment rates, and the balance of payments; the scope for substitution between energy and other factors of substitution; and the effect of energy prices on income distribution and employment.

The Sri Lanka model is meant to illustrate how a simple computable general equilibrium model focussing on these issues can be built rather quickly in a situation with substantial data limitations. The model was constructed with data from existing sources, supplemented by some minimal econometric estimation, and was designed to run on a personal computer.

The model includes eleven sectors: (1) paddy and other annual agricultural crops; (2) tree crops; (3) industry; (4) transportation; (5) housing; (6) services; (7) refined petroleum products; (8) electricity; (9) non-competing imports; (10) crude oil; and (11) traditional fuels. Prices determine factor allocations, production, and final demands. Trade flows are adjusted to ensure that total supply equals total usage. For the tradable goods, prices are exogenous. Electricity prices also are set by government policy. The model calculates prices for transportation and housing which insure supply/demand equilibrium for these non-traded sectors. The model is "closed" by specifying a rule for relating aggregate investment and the balance of payments deficit to national income (GDP). In some cases, the trade deficit is fixed in terms of GDP, and in others aggregate investment is fixed as a share of national income.

Starting from a base year of 1983, the model simulates developments through 1989. Several alternative solutions are discussed to demonstrate how parametric changes can show the sensitivity of key variables to changes in prices, economic policy, and the external environment.

I. Introduction

In this paper, we report on the results of a research project addressed at modelling energy-economy interactions in small developing countries.[1] The overall objectives of the research were to learn more about how energy-economy interactions can be usefully modelled for policy purposes, to compare the pros and cons of alternative methods which have been used previously, and to test the feasibility of utilizing simple general equilibrium models by constructing an illustrative model for Sri Lanka. The focus of the project was largely on methodology.

Most previous studies of energy demand in developing countries have used partial equilibrium methods.[2] That is, energy demands are projected on the basis of exogenously forecast sectoral or macroeconomic growth, with or without sensitivity to variations in energy prices. The problem with this approach is that for many developing countries, the level of energy demand and the associated costs of meeting these demands is likely to have a significant impact on the macroeconomic variables and sectoral growth, which have been projected independently of the energy situation. It is this feedback of energy costs and demands on the rest of the economy--including aggregate growth, the balance of payments situation, and the sectoral pattern of growth--that we have in mind when referring to "energy-economy" interactions.

These interactions probably are more significant for developing than developed countries because the former are more dependent on imported oil than most OECD countries, and financially they they are in a weaker position to cushion any oil price shocks. At the same time, their economies are changing at a more rapid rate, generally characterized by increased industrial production and urbanization, both of which tend to be energy-intensive.

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[1] This project was sponsored by the Office of Energy of the Agency for International Development.

[2] For example, see Choe (1978), Dunkerley (1982), and Wolf et al. (1981).

As described in the next section, there are several methods available for modelling these kinds of two-way feedbacks. The alternatives vary with respect to: data requirements, the economic or policy issues which are given special attention, and the economic behavior underlying the models. Which method is "best" depends in large measure on the scope and intensity of the energy-economy interactions. More complicated methods would be appropriate for, say Mexico, with its large petroleum and industrial sectors, than for say Kenya, even if they had similar data bases.

Here, we are specifically concerned with the smaller, less industrialized developing countries. We refer to countries with populations less than 20 million or so and where neither the industrial or energy sectors are dominant. This set would include a number of countries in South and East Asia, sub-Saharan Africa, and the island economies. In designing an appropriate methodology, we also have tried to take into account typical data limitations and the limitations on the amount of real resources (manpower, computer costs, etc.) available to undertake this type of policy modelling.

After reviewing various alternative, we reached several general conclusions about what types of models are most appropriate. For the type of country we have in mind, the model should be focused specifically on the key energy-economy interactions, rather than address all interesting macroeconomic and planning issues. In most situations, we would recommend using rather simple general equilibrium models for this purpose. These have a number of advantages. They embody the interdependence among the sectors and between the foreign trade situation and macroeconomic variables. Their structure not only insures full multisectoral consistency, but builds in conventional microeconomic behavior by private consumers and producers.

A multisectoral approach, even if only a small number of sectors are distinguished, is extremely useful as a way of capturing the sensitivity of energy demand growth to structural change and the sensitivity of structural change to changes in the energy situation. The models should allow for the feedback of energy prices on the household consumption and production demands for energy. This, too, is something for which general equilibrium models are well-suited.

Although it would be, in principle, desirable to have a model which determines the optimal or efficient level and composition of investment, that is too ambitious for most countries. On the other hand, an energy-economy model should be capable of making at least medium term projections. This is important because many of the adjustments to changes in energy costs or energy supply policy occur with quite long lags.

We have used Sri Lanka as a test case to illustrate how such a model can be built rather quickly in a situation with severe data limitations. The Sri Lanka model was constructed in less than a month, and initially tested and implemented during a visit of only several weeks to Colombo in the summer of 1984. The data come from existing sources (mainly from the Statistical Office, the Central Bank, and the Energy Ministry), supplemented by some minimal econometric estimation. The model has nine sectors (including three energy sectors), eleven goods and services, two consuming groups, and a partial set of government flow accounts. It was designed to run on a personal computer.

The next section summarizes our review of alternative methods for investigating energy-economy interactions. Six general approaches are discussed and then compared. This section also contains a discussion of the use of simple general equilibrium models in small countries. Section III presents the formulation of the specific model for Sri Lanka. Here we emphasize the reasons why certain aspects of the economy where given more attention and others less. Section IV is a discussion of the initial results of the model. In additional to a Base case, we explore some of the implications of possible changes in world or domestic oil prices. Finally, there is a brief concluding section.

II. Assessment of Alternative Approaches to Energy Policy Models

A survey undertaken by this project of alternative energy policy methodologies, "Models of Energy-Economy Interactions for Developing Countries: A Survey," by Sunwoong Kim revealed a number of different approaches.[3] These reflect the different countries and problems for which they were intended as well as the different analytical techniques which were applied. As experience with the analysis of energy-economic issues has expanded, a better realization of the essential nature of the issues has been achieved and more powerful tools have been developed. To some extent, early methods have been superseded, but some remain useful in particular circumstances. As an introduction to the presentation of the model developed for Sri Lanka, alternative methodologies for energy-economy policy analysis will be examined, relying on the survey by Kim, in order to place in context the approach which was adopted in this project for Sri Lanka.

In this section, we first review alternative methodologies for energy policy modelling, then provide a brief appraisal of their usefulness, and close with a discussion the use of simple general equilibrium model for small, less industrialized developing countries.

Project Evaluation

In some ways the most basic policy problem is that of deciding whether to devote resources to a particular energy project. The standard way of dealing with this is a project evaluation and standard programs are available to do this.[4] There are several drawbacks to the standard programs. They do not deal with the difficult, but often central, problems of determining the correct shadow prices, including the shadow discount rate, which will

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[3] See Kim (1984).
[4] Project models such as Envest are discussed in Kim (1984).

correctly evaluate the real social costs of the resources to be used and the outputs. This is because the methods are essentially myopic with respect to the rest of the economy, with respect to intertemporal decisions and concentrate only on the particular project. Another aspect of the myopia is that the calculations do not take into account the overall riskiness of the "portfolio" of projects in the energy area and the evaluation is carried out independently of other projects which may be under consideration.[5] To become more useful, the project evaluation techniques must include a methodology for estimating shadow prices, which is an undertaking of a different type.

Technology Assessment

Technology assessment or energy sector optimization is another modelling approach. It starts from a given energy demand forecast, whose origins are not of concern to the model itself, and finds the "optimum" mix of energy energy projects which will satisfy these demands. The criterion function which is minimized is usually total cost in the entire energy sector, and only in the energy sector. The technological possibilities are represented by linear functions in some cases as if there were no committed capital equipment in place. This type of model allocates resources and makes technological choices as if starting from a clean slate, which must obviously overstate the potential rearrangements which are desirable, as well as the desirability of some new projects. Since most such models use the "energy reference system" developed in the Brookhaven National Laboratory, there is some questions as to the currency and relevance to particular developing countries of the technologies and associated costs.[6]

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[5] For examples related to oil exploration, see Blitzer, Cavoulacos, Lessard, and Paddock (1983).
[6] See Kydes, Cherniavsky, and Babinowitz (1976).

Energy Sector Assessments

Many energy sector assessments are carried out which do not rely on an explicit modelling analysis. The studies typically include detailed investigations of particular features of the energy producing sectors and particular areas of demand as well as analyses of policy approaches to specific problems. They often contain insightful information which, however, will be at different levels of detail. The pattern of development ascribed to the economy being studied is typically based on some other sources. The implicit or explicit demand and supply elasticities which are employed in these reports are also usually taken from other sources for the particular country or the report may rely on estimates made for another country which is assumed to be similar.

The World Bank, the U.S. Agency for International Development and other international and national agencies frequently commission such studies. Groups of experts with previous country and energy sector experience are assembled for the purpose.

This approach typically suffers from three types of deficiencies. First, it will not be comprehensive. It is frequently true, for example, that energy demands and supplies in the agricultural sector are not investigated, although the characteristics of the "traditional" energy sectors, may be studied. Secondly, the analyses and recommendations of the various parts of the report will not necessarily be consistent. That is because, there is no overall framework which is imposed on each sector and on demand and supply conditions, and, thus, there is no way of insuring consistency. Finally, and, perhaps, as an aspect of the former point, this type of study cannot take into account the interactions between the energy sector and the rest of the economy. As a result, the studies cannot reveal the full effects on either the energy sector or the rest of the economy of changes which might be proposed or might take place.

Macro Simulation Models

This category covers several different types of models which have in common the feature that they cover the entire economy and generate forecasts of aggregate variables as well as energy sector variables. The models will typically distinguish from a few to a substantial number of sectors and may embody a set of input-output coefficients for estimation of intermediate demands. There will, as well, be a set of macroeconomic relations which generate the projections of the aggregate variables.

It would appear that this methodology might solve the problem of achieving consistent energy-economy interactions. This is not the case because the causal relations between the energy sectors and the economy as a whole go in only one direction in the calculations for a particular period. Aggregate economic variables are used to calculate energy demands. Energy supplies and prices also will be calculated, or will be assumed. These results will be used in projecting aggregate aggregate variables in a subsequent period.

The dynamic relations embodied in such models are typically relatively simple with each period's economic activity building on the period before and affecting only the next period. There is no foresight and the intertemporal interactions are highly simplified.

There are, however, many differences among the models of this general type. In some cases, the energy sector is treated in a sophisticated manner being represented by an optimizing process intended to reflect the outcome of myopic, but otherwise perfect market processes or skilled planning.[7] There is

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[7] Examples include Blitzer (1985), Hill (1983), Hoffman and Jarass (1982), Modiano (1983), Mukherjee and Rahman (1982).

also a danger of instability in such models, if the sectoral balance equations for several sectors, such as the investment supplying sectors or the energy supplying sectors take the form of difference equations.

Economy-Wide Optimization Models

Models of this type achieve the goal of embodying the mutual interactions between the energy sectors and the rest of the economy instead of having only one way causal relations. They also avoid the instability properties of multisector difference equations models and find a unique solution which is optimal in terms of the criterion function which is being maximized or minimized.[8] There will be one or more energy producing sectors and the energy demands for consumption and production purposes will be described separately.

These models typically cover a number of time periods. They also have an number of sectors, one or more of which is an energy producing sector, which respond to the demands on them for intermediate and final products. The intermediate demands are nearly always determined by an input-output matrix with fixed coefficients, although in a recent model these fixed energy coefficients are replaced with a set of alternative input requirements.[9] The demands for personal consumption by sector may be determined simply as shares of total consumption which is being maximized or, in a much more satisfactory manner, by their contribution to total utility which is maximized. The latter method makes it possible to introduce explicitly the energy demand functions of consumers.[10]

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[8] For a comprehensive discussion of early examples of such models see Blitzer, Clark, and Taylor (1975). More recent models of this type include Blitzer and Eckaus (1983) and Tourinho (1985).

[9] See Blitzer and Eckaus (1983).

[10] For examples of alternative ways this can be done, see Goreux (1975), Blitzer and Eckaus (1983), and Tourinho (1985).

Government and export demands are usually specified exogenously, though the latter can be determined endogenously in response to export demand functions. Investment demands are determined by the maximization process but consistently with specified inputs requirements for the components of capital. As was done in a recent model, it is possible to specify alternative capital, energy, labor input activities, one of which is chosen in each period for whatever new investment is carried out in each sector. Imports by sector type can also be determined by simple fixed coefficient relations to output, or considered as a residual supply or deduced as part of the maximizing process which finds the "cheapest" way of producing the output desired, consistent with the constraints imposed. Internationally traded energy imports can be handled in this manner, with non-traded energy inputs, which cannot move in international trade being generated by domestic production.

The constraints embodied in such models are the usual sectoral balance and foreign exchange balance conditions as well as the production conditions which, for investment, determine the time required to produce new investment goods. There may be other constraints which relate, for example, the cost of foreign borrowing to the amount of borrowing and the rate of drawdown of oil reserves to the rate of exploitation of the reserves. It is possible to approximate non-linear relations in a satisfactory manner except for increasing returns to scale types of production. The latter can be handled only if it occurs infrequently in a model.[11]

The advantages and disadvantages of economy-wide optimizing models depend, of course, on the particular formulations of its various components.

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[11] Blitzer and Eckaus (1983) use linear approximations to solve such "non-linear" formulations using linear programming methods. Illustrating the rapid improvements in available software, Tourinho (1985) handles non-linearities directly using a non-linear programming algorithm.

The models, in any case, are sectorally and intertemporally comprehensive and internally consistent. The intertemporal decisions are made taking into account the entire relevant planning period, as would be desired in a policymaking process. In their simpler, completely linear forms the models suffer from intertemporal "flip-flop", tending to concentrate all the maximized consumption at the beginning or, more usually, at the end of the planning period. When convexities are added in the consumption-utility functions, the production functions, the foreign borrowing and oil reserves-depletion relations and in absorptive capacity constraints, the flip-flop problem is eliminated.

While such models have many advantages as compared to those described previously, they also have some drawbacks. The economy which the models simulate is one with perfect markets and perfect foresight. Thus the models are normative and the adjustment of their projections to real conditions requires careful judgment. One aspect of this limitation is that it is difficult to specify price policies and constraints which may prevail in reality, for example in fixed wage levels in some sectors, or which might be considered as a matter of policy, for example, taxes and subsidies.

<u>General Equilibrium Models</u>

Although the previous models are a type of computable general equilibrium model, the latter term is generally used to refer to static models of a perfectly competitive economy for which solutions are calculated.[12] The models have many of the features of optimizing models and also capture the interactions between the energy sectors and energy policy and the rest of the economy. The models contain a number of sectors, including one or more energy

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12 For a discussion focussing on developing country applications, see Dervis, de Melo, and Robinson (1982).

sectors. There may also be a number of time periods but, whereas in the multiperiod optimization models the results for each year take all the periods covered by the model into account, the intertemporal effects in the general equilibrium models are myopic. The time structure of the models is recursive and each period builds on the previous period but is not affected by the next period.

The production technologies embodied in these models can be linear and/or non-linear, depending on the sector and the factors, so that capital-labor-energy substitutability or complementarity can be reflected. Increasing returns to scale relations are completely ruled out in this methodology as in most others. Typically, intermediate requirements are determined by an input-output coefficients table and primary inputs are determined by production functions which embody substitution possibilities, either in a Cobb-Douglas or a CES form. In some recent models, intermediate energy inputs are removed from the input-output table and treated as if they were a primary factor so that the possibilities of substituting for or against energy can be included in the model.[13]

Consumption demands for energy and other goods can be determined by the specification of consumer utility functions or the demand equations which they imply. Export demands are usually specified exogenously, although they can be made a function of the domestic prices which are generated. Imports can be determined either by fixed coefficients or, again, related to foreign prices which have to be exogenous to the model and endogenously determined domestic prices.

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[13] For an example applied to Mexico, see Blitzer and Eckaus (1983).

Investment is either exogenous or determined endogenously, in total, by the level of savings and allocated among sectors according to the relative shadow prices on capital stock in each sector. Since these relative shadow prices reflect only current conditions and not the future demands for investment, savings and capital stocks, the models are, as noted above, myopic.

Government taxes and subsidies on goods and resources can be specified explicitly sector by sector and according to the use of the goods and resources. Functional incomes are determined and the distribution of personal incomes can be derived by allocating shares of ownership of factors to different income classes. Taxes and subsidies can be specified on particular goods and factors and by income class.

As can be inferred, the particular advantage of this type of model is in the ability to analyze the implications of price policies for petroleum and other energy sources, for example. In addition, the effects of alternative price interventions on energy and other inputs and outputs, through taxes and subsidies can be analyzed. These effects may operate on private domestic consumption, production and imports. Although most models of this type assume market clearing prices, it is possible to specify, exogenously, fixed prices for goods or services which do not clear the markets. The effects on the distribution of income of changes in energy and other prices and the feedback effects on demands can be investigated.

The disadvantages of such general equilibrium models are in their limited and myopic dynamics and, also, in their commitment to a competitive structure, except where prices are fixed exogenously.

Appraisal of Alternative Energy-Policy Modelling Methodologies

The "best" choice among the alternative approaches to energy policy modelling depends on the issues to be analyzed in the particular country and the time and resources which can be employed. Yet, although the techniques which are conceptually the most satisfactory require more time and resources than the least satisfactory, it is often the case that improvements can be achieved with relatively little cost. Both the objectives of the analysis and time and resource constraints will be kept in mind in appraising the alternatives.

The objectives of energy policy modelling in developing countries vary from the design of an integrated energy and overall economic development policy to the appraisal of a single small project. There are, typically, intricate interactions between energy policy and overall economic performance. Thus, unless the project is small relative to the economy and the energy sectors as a whole, even a single undertaking should be appraised taking into account its overall consequences. Most of the approaches to energy policy modelling are intended to do this, but with different degrees of ambition and success.

Project evaluation, focussing on individual undertakings, might appear to be completely unable to take into account overall energy-economy interactions. Yet, the use of shadow prices in evaluating inputs and outputs ties the individual project evaluation to the entire economy. The shadow prices are intended to reflect for the economy as a whole the marginal costs of the resources employed and the marginal benefits of the outputs achieved. The methods of project evaluation, however, are intended to finesse the overall analysis through shadow prices which make the correct linkage between the individual undertaking and overall development. If the intention is achieved, therefore, project evaluation is carried out as if it were embedded in an overall energy-economy analysis.

That is a goal which cannot ever be attained fully but can be approximated in certain circumstances in which shadow prices can be estimated without a comprehensive analysis. One condition is that the project must be relatively small and not set off a chain of events which change the character of an important part of the economy within several years or or so after its completion. Another condition is that the current prices in the economy must not be completely unrepresentative of real relative scarcities or that international prices can be used to evaluate most of the inputs and outputs. Then current relative prices, with some critical adjustments, can be used to calculate shadow prices.

These conditions will hold to a reasonable degree in many countries for many undertakings, so that project evaluation techniques are, and will be, an important tool. It is clear that the techniques are simply not useful for the sectoral investment decisions and other policies, such as those on pricing, which affect the entire economy.

The conditions under which technology assessment methods will be satisfactory are much like the conditions under which project evaluation methods succeed. The starting point for the technological assessment must not be too far away from the actual current conditions since the technological choices in the energy sectors are explicitly assumed not to feed back into overall development of the economy. If that is not so, the final results of the technological assessments will be different from the economic assumptions on which those assessments were based. Unfortunately there is no reason to believe that successive iterations will resolve the inconsistencies. However, in countries which have been relatively open to energy price changes and in which markets have operated with relative effectiveness, the technology assessment techniques may, themselves, give useful details. To state the conditions, however, is to make apparent the limited scope of such techniques, when used by themselves.

That does not mean that technological assessments are without value. If, when such an assessment is carried out, the types of technologies which are chosen are substantially different from those which are in place, that would be a strong indication that further studies are highly desirable. At the end of a study which does take energy-economy interactions into account, a technology assessment can be used to check specific aspects of the results and to provide more technological detail. It would, of course, be absolutely essential that the technological data and cost information included in the assessment be up-to-date.

Overall energy assessments, can provide a background information as well as some detailed evaluations of particular energy demands and supplies and other related policies. They cannot provide a comprehensive basis for policy but they can be quite useful when there are strong reasons to believe that the major energy problems and their solutions are readily identifiable. This can be the case in economies with a relatively simple economic and/or energy structure, for example an economy in which agriculture accounts for, say, 75 per cent or more of the gross national product and the only nontraditional energy source is, and will be, imported petroleum. In such cases energy demands can be readily identified and energy policy formation, at least with respect to imports and their domestic use will be straightforward.

That is not to say the problems will actually be easy ones to resolve. The energy supplies to the agricultural sector may be quite difficult, for example, if local fuel wood is being depleted. The problems can be isolated, however, and do not require overall modelling for successful analysis. It may be necessary to carry out sophisticated forestry and transportation studies but those can be expected to be different for each country.

It is as much of a mistake to be analytically more sophisticated than a problem requires as it is to be less sophisticated than necessary. Overall energy sector assessments can embody general collections of data, identify problems and develop special purpose analyses, all of which can be quite useful in particular circumstances. The approach cannot deal with interacting energy-economy policy issues in even a moderately sophisticated economy and should not be expected to do so.

Macrosimulation models, as noted, are formulated in a number of different ways in covering an entire economy. In general such models generate for one period, or for several periods, not only aggregate economic variables, but sectoral detail. Their structure is such that this detail is produced in a rather mechanical way, either without interactions between the energy sectors and the economy as a whole or with only one way interactions. It is as if an economy and the energy parts of it were a wind-up toy that will climb steps when set off on its own. Such models do not have built into them procedures for choices among alternatives and for adjustment of their paths depending on such choices, except, in some cases, where energy technology choices are made in one period which affect output levels in the next period.

The intent of the macrosimulation models, to have a comprehensive approach to energy policy formulation, is praiseworthy and, as such, it represents, in some ways, an advance over the previously discussed methods. The fatal disadvantage is their mechanistic structure. This not only makes it impossible for them to deal with such important issues as price policy, but can even lead to serious errors when the fixed consumption, input and output patterns are projected into the future. Finally, the data base necessary for the construction of macrosimulation models needs only modest amplification to serve in the formulation of the more satisfactory economy-wide optimization and general equilibrium models.

The <u>economy-wide optimization models and the computable general equilibrium</u> models each have some of the features most desired for energy policy analysis. These models can take into account interactions between the energy sector and energy policy and developments in other sectors and the economy as a whole. Although they could be disaggregated to include specific large projects, they are typically formulated with relatively few sectors. Thus they are not as versatile and convenient as project evaluation techniques for the assessment of small projects. Nor do such models provide much technological detail. On the other hand, the optimization and computable general equilibrium models do everything that macrosimulation models can do, do it in a more satisfactory manner and utilize the data assembled more effectively.

The choice between economy-wide intertemporal optimization models and computable general equilibrium models depends on the nature of the policy issues to be addressed. Both models take intersectoral interactions into account. Both allow for technological choices in the energy sector which reflect the relative demands and supplies of energy sources of various types and uses in the different consuming sectors. Both generate shadow prices which reflect the real relative scarcities of energy and other productive resources and other inputs and outputs in the economy. The differences between these two broad types of models are mainly in the effectiveness with which they deal intertemporal issues and the convenience with which alternative types of policy issues can be studied.

If the central policy issues at a particular moment are decisions about major sectoral investment programs and other intertemporal policies with respect to the overall patterns of energy sector development in relation to the economy as a whole, then the intertemporal optimization models almost certainly dominate. As noted above, the computable general equilibrium models treat intertemporal questions in a rudimentary and myopic manner. By comparison in the optimization models it is possible to make policies over a long planning horizon which are consistent and even optimal with respect to a specific criterion function.

On the other hand, the important sectoral development programs may be deducible without sophisticated techniques because of the clear dominance of some programs or they may have been decided for the near future. In this case the current issues will be the implementation of the programs via price policies and the consequences of alternative policies. Then the computable general equilibrium models have distinct advantage. In these models it is easier to impose and find the static consequences of alternative tax and subsidy policies which affect prices. It also possible to develop some approximations as to the income distribution effects of the alternatives as well as the macroeconomic effects.

Simple General Equilibrium Models for Small,Less Industrialized Developing Countries

The situations of small developing countries will often fit the circumstances in which general equilibrium models will be the most effective tool for analysis of energy policy issues. In these countries, the major source of energy for urban consumers and industry typically will be petroleum imports and, possibly, electricity from hydro projects. The major intertemporal decisions with respect to the sectoral allocation of investment will often be relatively straightforward and not require the sophisticated techniques of economy-wide optimization models. For example, the countries are often predominantly agricultural with a clear advantage in a few particular crops. Or the countries may have a major mineral resource whose exploitation must provide most foreign exchange earnings. In these circumstances an economy-wide intertemporal optimization model is not likely to provide better first approximations than are already available unless substantial effort is put into the generation of detailed data for such a model. Likewise, if it is necessary to develop a mix of light industries to supplement the agricultural sectors, optimization models are also not likely to be helpful. The highly disaggregated data necessary to include a number of different small sectors in an optimization model are not likely to be available.

By comparison, even when the major lines of investment and sectoral development are relatively clear, the policies which will implement these energy programs and the consequences of alternative policies for government finance will not be obvious and will have to be worked out in detail. The computable general equilibrium models will be most effective for these purposes.

Both because of data limitations and because the types of policies to be developed are quite general in nature, the general equilibrium models will have to be and can be relatively simple. With respect to sectoral detail, it will be desirable to distinguish several energy sectors and sources and the major agricultural and, perhaps, mineral products. It will generally not be necessary to have many separate industrial and service sectors. Information on sectoral consumer demands and investment programs will have to be added and major tax and subsidy programs will need to be taken into account.

It will always be necessary to be alert to the need to use the analytical tools most suited to the particular situation. However, simple general equilibrium models for the analysis of energy policy in the context of general economic development will have the highest priority for a substantial class of countries.

III. Formulation and Description of the Sri Lanka Model

There are numerous aspects of energy-economy interactions which could be considered, since energy is an important input throughout the Sri Lankan economy. Among the most important questions which might be considered are: (1) the impact of energy costs and prices on aggregate growth and its sectoral composition; (2) the relationship between energy imports, investment rates, and the balance of payments; (3) the scope for substitution between energy and other factors of substitution; (4) and the effect of energy prices on income distribution and employment. The time horizon also is important, since many adjustments to higher energy prices and costs take many years to complete.

This implies that if there were such a thing as an "ideal" model, it would be disaggregated into many sectors of production with endogenous factor substitution, have many consumers with different factor endowment and consumption behavior, contain a complete set of fiscal accounts, include foreign borrowing opportunities, embody efficient rules for savings generation and allocation of investment, etc. While theoretical models could be formulated with these characteristics, in practice no single model could serve all these diverse purposes.[14]

The model prepared for Sri Lanka is in the same spirit as the medium-term general equilibrium models in which prices determine factor allocations, production, and final demands. Investment is determined by some "closure" rule, and this generates the capital stocks used to calculate a solution for later years. As noted above, this procedure is not fully satisfactory, since it does not guarantee that investment decisions are made efficiently or optimally. While arguably, a dynamic optimizing model focussing on

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14 For reviews of these methods, see Blitzer, Clark, and Taylor (1975), Taylor (1979), and Dervis *et al.* (1982).

intersectoral investment and technology choice might be the most desirable to analyze the energy-economy problems of Sri Lanka, construction of such a model was not feasible in this project. Neither the necessary data nor manpower were available.

As with all economy-wide general equilibrium models, we specify a discrete set of sectors producing goods and services which are bought and sold. Most of these must be aggregates of similar commodities in order to stay within data limitations and to keep the size of model within manageable limits. In this model, there are eleven sectors: (1) paddy and other annual agricultural crops; (2) tree crops; (3) industry; (4) transportation; (5) housing; (6) services; (7) refined petroleum products; (8) electricity; (9) non-competing imports; (10) crude oil; and (11) traditional fuels.

All of these except for crude oil and the general category "non-competing imports" (which is primarily capital goods) are produced in Sri Lanka. Thus the model keeps track of domestic production in nine sectors which generate all domestic value added. Of these, six are non-energy sectors. International trade is allowed in agricultural and industrial goods, as well as in services (e.g., tourism). Housing and transportation are non-traded, which means that domestic supply must equal domestic demand.

Three energy sectors are distinguished. The refining sector uses crude oil (which must be imported) to produce products which are used in the production process of other sectors and by households and the government. Any shortfalls or surpluses can be balanced by imports or exports. Electricity is produced either by hydropower or by thermal generation (using petroleum products as an fuel) and, of course, is non-tradable. Traditional fuels (such as wood and crop wastes) are also non-tradable.

The transactions matrix for 1983 (the base year) is presented as Table 1. Along the rows of this table shows the deliveries (or sales) of each good to other sectors, domestic final demand categories, and foreign trade. Net imports are positive for those sectors in which imports exceed exports, and are negative where imports are greater than exports. The columns of the transactions matrix show the amounts of each good purchased by the various sectors, households, the government, and investment. Consistent accounting implies that the sum of final demands must equal the sum of value added. In effect, the model is designed to project such transactions tables for future years. These then indicate changes in aggregate growth, sectoral composition, energy demands by sector, foreign trade, etc.

Generally, the model calculates the level of sectoral production in a year as a function of the level of previous investment in that sector and the output and input prices and wages that the sector faces. Non-energy intermediate demands are derived using fixed input-output coefficients. More sophisticated procedures are used to calculate the energy demands of each sector. In these latter procedures, the input-output coefficients become variables which change in response to the relative prices among energy sources and the relative price of energy and non-energy inputs.

Labor demand in tree crops, industry, transportation, housing, and the service sectors depends on both output and the real wage. Employment in electricity and refining, which accounts for only a small proportion of total employment, are exogenous. Employment in paddy agriculture is not modelled explicitly, implicitly assuming surplus labor in this sector. This roughly corresponds to the assumption of a "dual" labor force, which is a realistic approximation for most developing countries and is used typically in these types of macromodels.

Table 1: 1983 TRANSACTIONS MATRIX AT PRODUCERS PRICES
(UNITS: BILLIONS OF 1983 RUPEES)

SECTORS	PADDY AGRIC	TREE CROPS	INDUSTRY	TRANSPORT	HOUSING	SERVICES	PETROLEUM PRODUCTS	ELECT.	TRAD. FUELS	TOTAL INTERMED DEMAND	RURAL CONSUMP.	URBAN CONSUMP.	PUBLIC CONSUMP.	GROSS INVESTMENT	NET TRADE	TOTAL FINAL DEMAND	TRADE AT BORDER PRICES IMPORTS	TRADE AT BORDER PRICES EXPORTS	GROSS OUTPUT
PADDY AGRICULTURE	1.467	0.115	8.267	0.000	0.000	0.022	0.000	0.000	0.000	9.871	16.588	4.146	0.195	0.000	-2.538	18.343	4.826	-0.138	28.214
TREE CROPS	0.000	6.040	0.525	0.000	0.000	0.000	0.000	0.000	0.000	6.565	2.196	0.387	0.000	0.000	10.681	13.265	0.000	2.670	19.830
INDUSTRY	2.740	1.660	6.324	0.522	0.374	1.606	0.007	0.624	0.000	14.355	15.736	8.661	1.657	14.823	-2.741	38.136	10.318	0.548	52.491
TRANSPORTATION	0.406	0.153	2.903	0.686	0.051	0.379	0.237	0.122	0.000	4.937	9.147	3.049	0.975	0.000	0.000	13.171	0.000	0.000	18.113
HOUSING	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.880	1.235	0.000	0.000	0.000	4.115	0.000	0.000	4.117
SERVICES	0.894	0.157	6.782	1.614	0.117	2.407	0.119	0.171	0.000	12.260	18.288	6.096	4.873	0.000	2.002	31.259	5.350	0.000	43.519
REFINED PETROLEUM	0.000	0.087	0.538	3.004	0.000	0.287	0.069	2.288	0.000	6.273	0.684	1.391	0.487	0.000	-0.421	2.142	3.182	0.114	8.414
ELECTRICITY	0.014	0.006	0.482	0.016	0.000	0.422	0.001	0.769	0.000	1.710	0.917	1.861	0.390	0.000	0.000	3.168	0.000	0.000	4.877
NON-COMP. IMPORTS	0.121	0.075	0.724	1.567	0.000	0.218	0.003	0.146	0.000	2.855	0.000	0.000	1.170	20.470	-24.495	-2.855	22.266	2.229	0.000
CRUDE OIL	0.000	0.000	0.000	0.000	0.000	0.000	7.819	0.000	0.000	7.819	0.000	0.000	0.000	0.000	-7.819	-7.819	7.819	0.000	0.000
BIOMASS	0.000	0.354	0.271	0.000	0.000	0.113	0.000	0.000	0.000	0.738	1.126	0.312	0.000	0.000	0.000	1.438	0.000	0.000	2.176
TOTAL INTERMEDIATE	5.643	8.646	27.316	7.409	0.541	5.453	8.255	4.119	0.000	67.383	67.562	27.141	9.746	35.293	-25.374	114.368	53.761	5.423	181.750
VALUE ADDED	22.571	11.183	25.175	10.704	3.575	38.066	0.159	0.759	2.176	114.368	0.855	1.123	0.000	0.000	0.000	1.978	INDIRECT TAXES		
WAGE INCOME	0.000	8.640	12.213	2.655	0.000	10.658	0.106	0.289	0.000	59.311	68.417	28.264	9.746	35.293	-25.374	116.346	TOTALS		
PROFIT INCOME	0.000	2.543	12.962	8.049	3.575	27.407	0.051	0.470	0.000	55.057									
GROSS OUTPUT	28.214	19.830	52.491	18.113	4.117	43.519	8.414	4.877	2.176	181.750									

Once the distribution of income is determined, the model calculates private savings and the composition of private consumption using the income tax rates paid by rural and urban workers and on profit income, fixed marginal savings ràtes, and price sensitive consumption functions.

Government consumption expenditures are assumed to grow at a predetermined rate regardless of the size of the government deficit, although this rate can be changed in alternative scenarios. On the revenue side, there are income and indirect taxes, the latter creating distortions between domestic and international relative prices. Once government investment is determined, the deficit can be calculated.

Imports of agricultural and industrial goods, services, and refined petroleum products are adjusted up or down in order to ensure that total supply (domestic production plus imports) equals total usage (intermediate demand, private and public consumption, investment, and exports). The level of crude oil imports depends on refinery production. The amount of other non-competing imports depends on sectoral production and total investment. The model is "closed" by specifying a rule for relating aggregate investment and the balance of payments deficit to national income (GDP). In some cases, the trade deficit is fixed in terms of GDP, and in others aggregate investment is fixed as a share of national income.

For the tradable goods, prices are exogenous. The implicit assumption is that, as a small country, changes in the level of Sri Lankan trade do not affect world prices.[15] Thus, for tradable goods, domestic prices are world

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15 While this is certainly reasonable for imports and industrial exports, Sri Lanka is a major producer of tea, rubber, and coconut products. Wide swings in exports of these may have an effect on world prices. This can be handled either by introducing a specific demand function into the model or by an iterative procedure in which prices are adjusted up or down depending what results the model has produced.

prices plus or minus any tariffs or subsidies, times an exchange rate which is exogenous. Electricity prices also are set by government policy. However, the model itself, calculates equilibrium prices for transportation and housing. These are adjusted to insure supply/demand equilibrium for these non-traded sectors.

Finally, the allocation in any one year of investment among the various sectors determines the amount of capital stock which is available in the following year for additional production. In this way the model can be run forward in time, calculating consistent paths for production, trade, investment, employment, income distribution, energy demands, and so forth. Since the model solves for only one year at a time, there are no computational difficulties in extending the time horizon for additional years. However, the myopic investment behavior of the model, in which investment allocations do not respond fully to intersectoral differences in rates of return, imposes an effective upper bound on how many years can be usefully tested. In model such as this, 10-15 years usually is an appropriate horizon.

The equations of the model are described in the following sub-sections. Lower case Latin or Greek letters represent fixed parameters, upper case letters represent endogenous variables, and upper case letters with a bar over them represent exogenous variables. The subscripts "i" and "j" represent sectors, "k" stands for income groups, and "t" stands for time periods. The symbol "Δ" is notation for changes in variables between two years. Numeric subscripts refer to specific goods and sectors as follows: 1=paddy and other annual agricultural crops, 2=tree crops, 3=industry, 4=transportation, 5=housing, 6=services, 7=refined petroleum products, 8=electricity, 9=non-competing imports, 10=crude oil, and 11=traditional fuels. Variables and parameters are defined in Tables 2 and 3.

Sectoral Production and Factor Demands

Paddy and Other Annual Crops

This aggregate sector primarily produces food. As shown in Table 1, this sector accounted for about 20% of GDP in 1983. Typically for developing countries, a much larger share of the labor force works in this sector, about 40-45%. The 1983 transactions matrix also indicates very little direct use of energy in production. However, indirect energy use is substantial. The most important intermediate inputs are industrial goods, which include fertilizers.

In terms of production, the basic assumption is that growth is primarily a function of the rate of new investment (i.e., land clearing, irrigation, machinery) which will be undertaken. That is:

(1) $$X_{1,t} = X_{1,t-1}(1-d_1) + (1/k_1)\Delta K_{1,t-1}$$

All intermediate demands, including direct energy demands, are calculated as fixed proportions of gross output.[16]

(2) $$INT_{j,1,t} = a_{j,1}X_{1,t}$$

Tree Crops

The tree crop sector includes tea, rubber and coconut production. Although this sector represents for only 10% of GDP, it accounts for about three-fourths of export revenue. Production is based on a plantation system, with wage labor, rather than a village system with family farms. Most of the sectors's direct energy needs are met by traditional fuels, with petroleum products being more important than electricity from the grid.

For this sector, changes in gross output between any two years are related to depreciation of existing capital stock and changes in the inputs of

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16 These proportions can be varied in different runs to test the effects of different kinds of technical change.

Table 2: Definition of Variables

C_t	Aggregate private consumption expenditures in year t.
$C_{i,t}$	Level of private consumption of good i in year t.
$C_{i,k,t}$	Level of consumption of good i by consumer group k in year t.
$E_{i,t}$	Exports of good i year t.
G_t	Aggregate public consumption expenditure in year t.
$G_{i,t}$	Level of public consumption of good i in year t.
GDP_t	Gross domestic product in year t.
GR_t	Government revenue in year t.
I_t	Aggregate investment expenditures in year t.
$I_{i,t}$	Demand to investment good i in year t.
IN_t	Aggregate real investment undertaken in year t.
$INT_{j,i,t}$	Intermediate deliveries of good j to sector i in year t.
$L_{i,t}$	Total employment in sector i, year t.
$M_{i,t}$	Net imports of good i in year t.
$P_{i,t}$	Domestic price of good i in year t.
$PC_{i,t}$	Domestic consumer price of good i in year t.
$PR_{i,t}$	Profits of sector i in year t.
$PW_{i,t}$	Border price of good i in year t.
$S_{k,t}$	Savings of group k in year t.
S_t	Aggregate private savings in year t.
TD_t	Trade deficit in year t.
$TRFS_{r,t}$	Government transfer payments to the rural sector in year t.
$TRFS_{u,t}$	Government transfer payments to the urban sector in year t.
$VA_{i,t}$	Value added in sector i in year t.
$X_{i,t}$	Gross output in sector i, year t.
XH_t	Gross output of hydropower in year t.

XT_t	Gross output of thermal electric generation in year t.
$Y_{r,t}$	Disposable income of the rural sector in year t.
$Y_{u,t}$	Disposable income of the urban sector in year t.
$q_{i,t}$	Proportion of total investment spent on good i in year t.
$\Delta E_{i,t}$	Increase in aggregate energy demand by sector i, year t. new capital stock.
$\Delta INT_{j,i,t}$	Increase in demand for energy input j by sector in year t.
$\Delta K_{i,t}$	New capital available to sector i in year t.
$\Delta L_{i,t}$	Labor employed by sector i in year t in conjunction with previous year's investment.

labor and capital using Cobb-Douglas production functions. This is also a "putty-clay" formulation in which the factor input proportions respond to relative price changes when new investments are made. But, once made, these cannot be changed during the life of the capital equipment. The more rapidly a sector grows or its capital stock "turns over", the higher the short run price elasticities.[17] That is:

$$X_{2,t} = X_{2,t-1}(1-d_2) + A_{2,t}\Delta L_{2,t}^{\alpha 2}\Delta K_{2,t}^{\beta 2} \tag{3}$$

$$L_{2,t} = L_{2,t-1}(1-d_2) + \Delta L_{2,t} \tag{4}$$

The first term on the right-hand side of equation (3) is the output which can be produced this year using the capital stock and technology which existed in the immediately preceding year. The second (more complicated) term represents new output in year t, and allows for substitution between capital and labor. The same approach is used in equation (4) to derive total labor demand.

Non-energy intermediate demands and electricity demand (which is small) are projected using exogenous input-output coefficients. That is:

$$INT_{j,2,t} = a_{j,2}X_{2,t} \tag{5}$$

for all j, except for j=7,11 (petroleum products and traditional fuels).

Petroleum product and traditional fuel demands are derived in a more complicated way which allows the input-output coefficients to respond to prices. Specifically, the ΔE term in equation (3) refers to an aggregation of of these two types of energy, as shown in equation (7).[18] We assume that this aggregate demand for energy is complementary with capital, its total increasing in the same proportions as in equation (6).

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17 While these probably overstate the degree of substitutability among factors (and ignore complementarity entirely), they are used in this here because of their simplicity and the inferences which can drawn from national income accounts about parameter magnitudes.

18 A Cobb-Douglas aggregation is used.

(6) $$\Delta E_{2,t} = e_2 \Delta K_{2,t}$$

(7) $$\Delta E_{2,t} = H_2 \Delta INT_{7,2,t}^{h2} \Delta INT_{11,2,t}^{(1-h_2)}$$

Therefore, once demand for either petroleum products or traditional fuels is known, for any level of total energy use, the demand for the other can be derived. In this way, the model allows substitution between these two energy sources. Total energy demands for j= 7, 11 are:

(8) $$INT_{j,2,t} = INT_{j,2,t-1}(1-d_2) + \Delta INT_{j,2,t}$$

The model solves a sub-problem whose objective is the maximization of sectoral profits, given these equations, previous year's investment, the wage rate, and prices. The model hires labor and chooses the levels of energy demand in order to maximize:[19]

(9) $$P_{2,t}X_{2,t} - w_{2,t}L_{2,t} - \sum_j (P_{j,t} INT_{j,2,t})$$

Industry

The industrial sector accounts for almost one-quarter of GDP, and has in the past grown more rapidly than the agricultural or service sectors. It is also a sector which the Sri Lankan authorities believe has significant export potential. Perhaps surprisingly, Table 1 shows that existing industry is only a moderate user of energy. Total energy costs represent about 5% of value added. the sector uses about 10% of electricity and traditional fuels output and 6-7% of all refined products. Nonetheless, as a growing sector it may account for substantial new energy demands and thus it needs to be analyzed carefully.

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[19] The energy and labor demand functions can be derived straightforwardly by solving this problem.

Table 3: Definition of Constants and Parameters

$a_{j,i}$	Intermediate demand for good j, per unit of gross output of sector i.
ah_j	Intermediate demand for good j, per unit of gross output of hydropower.
at_j	Intermediate demand for good j, per unit of gross output of thermal generation.
b_i	Share of total public consumption spent on good i.
d_i	Annual rate of depreciation of capital stock in sector i.
d_h	Annual rate of depreciation in hydropower sector.
e_i	Aggregate energy demand per unit of new investment, sector i.
h_i	Energy aggregation elasticity parameter, sector i.
k_i	Incremental capital-output ratio in sector i.
k_h	Incremental capital-output ratio in hydropower sector i.
l_i	Demand for labor per unit of gross output in sector i.
s_i	Sector i's share of real investment in the non-energy sectors.
sh_i	Share of labor employed in sector i living in rural areas.
tc_i	Consumption tax rate on good i
tr_i	Tariff on traded good i.
tx_p	Tax rate on private urban profit income.
tx_r	Tax rate on private rural income.
tx_u	Tax rate on urban wage income.
v	Demand for investment goods form the industrial sector, per unit of real investment.
$w_{i,t}$	Wage rate in sector i in year t.
$A_{i,t}$	Scaling parameter for incremental production in sector i, year t.
H_i	Energy aggregation scaling parameter, sector i.
α_i	Labor's share of total incremental production cost in sector i.
β_i	Capital's share of total incremental production cost in sector i.

γ_i	Energy's share of total incremental production cost in sector i.
$\nu_{i,k}$	Share of incremental consumption spent on good i by consumer group k.
$\varphi_{i,k}$	Constant in consumption demand function for good i of consumer group k.

Production and factor demands are determined in the same way as described above for the tree crop sector. Capital and labor are substitutes in a Cobb-Douglas production function. Electricity demand and non-energy intermediate demands are derived using fixed coefficients. Capital and petroleum products and traditional fuels are complements, while these two energy sources are substitutes. Given previous investment, prices, and the wage rate, the model then solves in each year the following sub-problem.

Maximize:

$$P_{3,t}X_{3,t} - w_{3,t}L_{3,t} - \sum_{j}(P_{j,t}INT_{j,3,t}) \tag{10}$$

subject to the following equations:

$$X_{3,t} = X_{3,t-1}(1-d_3) + A_{3,t}\Delta L_{3,t}^{\alpha 3}\Delta K_{3,t}^{\beta 3} \tag{11}$$

$$L_{3,t} = L_{3,t-1}(1-d_3) + \Delta L_{3,t} \tag{12}$$

$$INT_{j,3,t} = a_{j,3}X_{3,t} \tag{13}$$

$$\Delta E_{3,t} = e_3\Delta K_{3,t} \tag{14}$$

$$\Delta E_{3,t} = H_3\Delta INT_{7,3,t}^{h3}\Delta INT_{11,3,t}^{(1-h3)} \tag{15}$$

$$INT_{j,3,t} = INT_{j,3,t-1}(1-d_3) + \Delta INT_{j,3,t} \tag{16}$$

Transportation

Like services and industry, the transportation sector is an important provider of intermediate inputs to the other sectors. It also accounts for about one-seventh of private consumption expenditure. Although value added in this sector is only about 10% of GDP, it is the largest single user of petroleum products, utilizing about three-eighths of total refinery output 1983. Future energy demand growth is expected to be quite sensitive to how fast transportation grows and with what energy efficiency.

In most respects, the transportation sector is modelled similarly to industry and tree crops. However, instead of capital and labor being substitutable, we assume that capital and petroleum products can be substituted for each other, with the trade-off rate depending on their relative prices. All other intermediate demands, as well as employment, are projected using fixed coefficients. The sub-problem is to maximize:

(17) $$P_{4,t}X_{4,t} - w_{4,t}L_{4,t} - \sum_j (P_{j,t}INT_{j,4,t})$$

subject to the following equations:

(18) $$X_{4,t} = X_{4,t-1}(1-d_4) + A_{4,t}\Delta K_{4,t}^{\beta 3}\Delta INT_{7,4,t}^{\gamma 3}$$

(19) $$L_{4,t} = l_4 X_{4,t}$$

(20) $$INT_{j,4,t} = a_{j,4}X_{4,t}$$

(21) $$INT_{7,4,t} = INT_{7,4,t-1}(1-d_4) + \Delta INT_{7,4,t}$$

<u>Housing</u>

The housing sector is small in terms of value added, accounting for about 3% of GDP. However, because the capital-output ratio is higher than in the other sectors, growth of housing can have important feedbacks on the macroeconomy. Even though housing uses only negligible amounts of energy directly, the size and quality of the housing stock can have indirect effects on household energy demand.[20]

Production and intermediate demands are calculated using fixed coefficients. The amount of growth depends positively on the level of investment in the sector and negatively on the rate of depreciation of the housing stock. The direct use of energy by this sector is small, since household fuel use is accounted for as part of private consumption, and

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20 In this version of the model, these feedbacks enter through the cross-price elasticities for energy with respect to the cost of housing.

related to sectoral output with a fixed coefficient. These relationships are expressed in the following equations.

(22) $$X_{5,t} = X_{5,t-1}(1-d_5) + (1/k_5)\Delta K_{5,t-1}$$

(23) $$INT_{j,5,t} = a_{j,5}X_{5,t}$$

(24) $$L_{5,t} = l_5X_{5,t}$$

Services

Services is the largest single sector in Sri Lanka, accounting for one-third of GDP. As indicated in Table 1, electricity is the major energy form used by services. But energy as a whole is not a very large part of total costs in this sector. For this reason, we also estimate future energy demand growth using a fixed coefficient approach.[21]

Capital and labor at the margin are substitutes in production, as is the case for industry and tree crops. Fixed coefficients are used in deriving the other intermediate demands. The sub-problem is to maximize:

(25) $$P_{6,t}X_{6,t} - w_{6,t}L_{6,t} - \sum_j(P_{j,t}INT_{j,6,t})$$

subject to the following equations:

(26) $$X_{6,t} = X_{6,t-1}(1-d_6) + A_{6,t}\Delta L_{6,t}^{\alpha 6}\Delta K_{6,t}^{\beta 6}$$

(27) $$L_{6,t} = L_{6,t-1}(1-d_6) + \Delta L_{6,t}$$

(28) $$INT_{j,6,t} = a_{j,6}X_{6,t}$$

Refining and Petroleum Products

This sector uses crude oil imports to produce products which are used for electricity generation, transportation, and by households and other

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21 As in the other sectors, conservation strategies may be tested by parametric alteration of the fixed energy demand coefficients.

sectors for many purposes. As Table 1 shows, the costs of crude oil dominate the price of these products. Domestic pricing policy is such that value added in the sector is very low, both absolutely and as a proportion of gross output. Table 1 also indicates that in 1983 about 5% of output was not used domestically and was exported.

In terms of technology, we treat refining as a fixed coefficients sector. That is:

(29) $$X_{7,t} = X_{7,t-1}(1-d_7) + (1/k_7)\Delta K_{7,t-1}$$

(30) $$INT_{j,7,t} = a_{j,7}X_{7,t}$$

(31) $$L_{7,t} = l_7 X_{7,t}$$

<u>Electricity Generation</u>

Electricity in Sri Lanka is generated by hydropower and thermal plants. Since the investment and intermediate cost structures of these are so different, the model treats these as two sub-sectors which produce the same good, electricity. In 1983, a large amount of petroleum products were used in electricity generation. But, as more hydrocapacity comes on stream, this level is expected to drop. The model is designed to capture these effects. That is, total intermediate demands depend on the sub-sectoral mix of generation in any one year. That is:

(32) $$INT_{j,8,t} = ah_j XH_t + at_j XT_t$$

The marginal operating costs of hydropower are less than for thermal generation. The sub-problem which the model solves, therefore, is to minimize thermal generation subject to several constraints. The first constraint (33) is that total generation must meet all demands for electricity, including transmission losses. Demands include household and government use, as well as purchases by other sectors of the economy. The second relationship is that total electricity supply is the sum of thermal and hydropower generation. Hydropower generation in each year is constrained by the amount of capacity available which depends on previous investments.

(33) $$X_{8,t} = C_{8,t} + G_{8,t} + \sum_j INT_{8,j,t}$$

(34) $$X_{8,t} = XH_t + XT_t$$

(35) $$XH_t \leq XH_{t-1}(1-d_h) + (1/k_h)\Delta K_{h,t-1}$$

(36) $$L_{8,t} = l_8 X_{8,t}$$

Traditional Fuels

No specific data is available describing the cost structure in this sector. As shown in Table 1, we assume that there are no specific intermediate demands and that all value added accrues to labor. On the production side, the model supposes that production exactly equals the sum of all demands. The "reasonableness" of any future supply pattern must be judged outside the model. If a run of the model has demand growing at an unsustainable rate, then adjustments (e.g., price increases, efficiency improvements) can be made on the demand side or through specific supply projects. Production is determined using the following equation.

(37) $$X_{11,t} = C_{11,t} + G_{11,t} + \sum_j INT_{11,j,t}$$

Value Added and Distribution of Income

Value Added, Profits, and GDP

Value added in each sector is defined as the difference between the value of gross output and the cost of all intermediate inputs. Sectoral profits are value added, less wage costs. Gross domestic product (GDP) is the sum of value added across all sectors.[22] In calculating these values, we use current (net of inflation) producers' prices. That is:

(38) $$VA_{i,t} = P_{i,t}X_{i,t} - \sum_j(P_{j,t}INT_{j,i,t})$$

(39) $$PR_{i,t} = VA_{i,t} - w_{i,t}L_{i,t}$$

(40) $$GDP_t = \sum_i VA_{i,t}$$

Rural Disposable Income

The gross income of the rural sector (which can be used for either consumption or savings) includes all the value added generated in the rural sectors (sectors 1, 2, and 11), and a share of wage income in the other sectors.[23] To get disposable income, an average tax is applied to this gross income and then government transfers are added. That is:

(41) $$Y_{r,t} = (1-tx_r)(VA_{1,t} + VA_{2,t} + VA_{11,t} + \sum_i(sh_i w_{i,t}L_{i,t})) + TRFS_{r,t}$$

Urban Disposable Income

Urban gross income includes all wage income not going to the rural sector, as well as profits from the industry, transportation, housing, and services sectors. Since the refinery and electricity sectors are public, their profits do not affect private income directly. In deriving private disposable income for the urban sector, separate tax rates are applied to wage and profit income, and government transfer payments are added. That is:

(42) $$Y_{u,t} = (1-tx_u)(\sum_i(sh_i w_{i,t}L_{i,t}) + (1-tx_p)\sum_i(PR_{i,t})) + TRFS_{u,t}$$

where the summation on profits covers sectors 3-6.[24]

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22 Value added can be calculated using any consistent set of prices. Base year prices are used to generate quantity indexes. Using border prices for traded goods is commonly used in studies of trade distortions. National accounts are typically done using purchasers' prices.
23 This is because many workers in the "urban" sectors live in rural areas.
24 Urban wage and profit income are aggregated because the expenditure data cover only rural and urban spending and do not treat profit income separately. More careful econometric analysis might be able to estimate the parameters needed to have three expenditure groups.

Government Revenue

Government revenue includes the income taxes applied to wages and profit income in the rural and urban area, the profits of the refining and electricity sectors, and indirect taxes. The model allows the government to specify tariffs on tradable goods and consumption taxes on all goods.[25] Total government revenue is determined using the following equation.

(43)
$$GR_t = PR_{7,t} + PR_{8,t} + tx_r(VA_{1,t} + VA_{2,t} + VA_{11,t} + \sum_i(sh_i w_{i,t} L_{i,t}))$$
$$+ tx_u(\sum_i(sh_i w_{i,t} L_{i,t}) + tx_p(\sum_i(PR_{i,t}))$$
$$+ \sum_i(P_{i,t} - PW_{i,t})M_{i,t} + \sum_j(PC_{j,t} - P_{j,t})C_{j,t}$$

In this equation, the first two terms are energy profits, the next three terms are income taxes on the rural and urban sectors, the next term is tariff revenue, and the final term represents consumption tax revenue.

Final Demand Expenditures

Private Consumption and Savings

Disposable income in both the rural and urban sectors is either spent on consumption or saved. The savings ratio for each group and the proportions of total consumption spent on each good are determined in the model on the basis of net disposable income and the prices which consumers face.

For both groups, an extended linear expenditure system is used to project a consistent set of these expenditures. These equations include a full set of price elasticities for consumption demand, including cross price elasticities. Parameters have been estimated separately for the two groups of

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[25] Tariffs act as a wedge between border and producers' prices, while the consumption taxes are wedges between producers' and final consumers' prices. These are significant policy variables for two reasons. Not only do they affect the size of the public deficit, but indirect taxes distort relative prices and thereby have an effect on technology choice and the composition of demand.

consumers. The following equations define how disposable income is allocated and define aggregate consumption and savings. Here, the "k" subscripts refer to either rural or urban consumers.

(44) $$C_{i,k,t} = \varphi_{i,k} + \mu_{i,k}(Y_{k,t} - \sum_j (PC_{j,t}\varphi_{j,k}))/PC_{i,t}$$

(45) $$S_{k,t} = (1-\sum_i \mu_{i,k})(Y_{k,t} - \sum_j (PC_{j,t}\varphi_{j,k})$$

(46) $$C_{i,t} = C_{i,r,t} + C_{i,u,t}$$

(47) $$S_t = S_{r,t} + S_{u,t}$$

(48) $$C_t = \sum_i (PC_{i,t}C_{i,t})$$

Government Consumption

The level and composition of public consumption are exogenous variables which can be set at different levels for each scenario. That is:

(49) $$G_t = \text{exogenous}$$

(50) $$G_{i,t} = b_i G_t / P_{i,t}$$

where the b_i sum to unity. Transfer payments to urban and rural households are also projected exogenously.

Investment Demand

There are two investment goods in the model. One type can be produced domestically by the industry sector (mostly construction, but also some machinery); other machinery must be imported and is classified as a non-competing import (good 9). Data availability (as well as a desire to preserve simplicity) necessities the assumption that the composition of the demand for specific investment goods (the proportions required of these two kinds of goods per unit of real investment) is not affected by the sectoral destination of the investments.

This assumption allows us to project the demand for investment goods on the basis of knowledge of aggregate investment expenditures and the prices of industrial and non-competing goods. While the physical proportions of investment demand (here, the parameter "v") are constants, the expenditure proportions on construction and machinery, the "q_i's", are endogenous and depend on relative prices. That is:

(51) $$I_{i,t} = q_{i,t}I_t/P_{i,t}$$

where,

(52) $$q_{3,t} = (vP_{3,t})/(vP_{3,t} + (1-v)P_{9,t})$$

(53) $$q_{9,t} = ((1-v)P_{9,t})/(vP_{3,t} + (1-v)P_{9,t})$$

Trade Flows

As discussed above, there are two types of traded good in the model, competing and non-competing. For the competing goods (sectors 1, 2, 3, and 6), the demand for imports is the difference between domestic demands plus exports, and domestic production. That is:

(54) $$M_{i,t} = \sum_j INT_{i,j,t} + C_{i,t} + G_{i,t} + I_{i,t} + E_{i,t} - X_{i,t}$$

For the non-competing goods (miscellaneous non-competitive imports and crude oil), there is no domestic production to subtract. For goods 9 and 10:

(55) $$M_{i,t} = \sum_j INT_{i,j,t} + C_{i,t} + G_{i,t} + I_{i,t}$$

Investment Allocations

Future production in each sector is determined, in part, by the level of investment in that sector in each year. In deciding how to allocate total investment among the various sectors, the model follows a predetermined set of rules. These rules represent alternative policies which the government might follow in its planning process.[26] These rules can be readily changed to test the implications of alternative investment policies.

We first calculate total real investment, which depends on expenditures and prices. That is:

(56) $$IN_t = I_t/(vP_{3,t} + (1-v)P_{9,t})$$

Real investment in the energy sectors is exogenous, part of the scenario plan, and these demands are satisfied first. Whatever investment resources are left over are divided among the other six sectors in predetermined proportions. For the energy sectors (i= 7, 8, and 11), we have:

(57) $$\Delta K_{i,t+1} = \text{exogenous}$$

For the other sectors (i= 1, 2, 3, 4, 5, 6), we have:

(58) $$\Delta K_{i,t+1} = s_i(IN_t - \sum_j(\Delta K_{j,t+1})$$

where the "j" index covers investment in energy sectors.

Model Closing and Solution

In order to have the model calculate a fully consistent set of accounts (similar to the transactions matrix shown in Table 1), only one more relationship need be specified. Consistency in national income accounting implies that the sum of value added across sectors (GDP) must equal domestic absorption (or spending), less the trade deficit and tariffs. That is:

(59) $$TD_t = \Sigma(PW_{i,t}(M_{i,t} - E_{i,t}))$$

(60) $$GDP_t = C_t + G_t + I_t - TD_t - \sum_i(P_{i,t} - PW_{i,t})(M_{i,t} - E_{i,t})$$

where the last term in equation (60) represents net tariff revenue.

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26 Although Sri Lanka has a mixed economy, the government exercises considerable direct and indirect controls over investment decisions, including intersectoral allocations.

To "close" the model, some rule relating investment expenditures and the trade deficit must be specified. As presently formulated the model can be solved using either one of two rules. In one, real investment is set to grow at an exogenously specified rate. This implied that adjustment costs in different scenarios will show up primarily in the trade deficit (and ultimately foreign debt) rather than in real growth. The other closing rule specifies a fixed time path for the trade deficit, which implies than the burden of adjustments which may be needed falls on investment and hence economic growth. Either (61) or (62) must hold.

(61) $$IN_t = \text{exogenous}$$

(62) $$TD_t = \text{exogenous}$$

Finally, there is the matter of how prices are determined. For the traded goods (i= 1, 2, 3, 6, 7, 9, and 10), border prices are taken as predetermined for the reasons discussed previously. So are tariffs, which means that for these goods:

(63) $$PW_t = \text{exogenous}$$

(64) $$P_{i,t} = PW_{i,t}(1+tr_i)$$

Similarly, the consumption taxes on each good are exogenous, which implies:

(65) $$PC_{i,t} = P_{i,t}(1+tc_i)$$

The price of electricity is also fixed by policy, with the model adjusting the level of thermal generation to insure supply and demand balance in the manner described above. However, there is no specific constraint which insures that for the other two non-traded sectors, transportation and housing, demand does not exceed supply. The model achieves this by adjusting the prices of these goods. That is, if transportation demand exceeds supply with one set of prices, the model raises the price to stimulate supply and dampen demand. The model finds a set of prices which satisfy the following identities (for i= 4, 5):

(66) $$X_{i,t} = \sum_{j} INT_{i,j,t} + C_{i,t} + G_{i,t} + I_{i,t}$$

IV. Results

General equilibrium models, even those as simplified as this one, can be used to analyze into a large number of interesting macro and microeconomic issues. Its multisector accounting structure allows the model to check on the internal consistency of the government's medium term economic scenario. Sensitivities and elasticities of key micro and macroeconomic variables to changes in prices, economic policy, and the external environment can be derived by running parametric changes on the model. To illustrate how the model can be used, we describe a few experiments which have been done, focussing particular attention on energy demand and prices.

Three cases are reported. The first case reflects the reported plans and forecasts of the government. This is the Base case, and it is used as a benchmark in measuring the other cases. In the latter cases, world oil prices increase faster than in the Base case. The higher world prices are not passed onto domestic purchasers in Case 2, while in Case 3 they are. The trade deficit is held constant (relative to the Base case) in these tests. Although the model can be run forward in time for 10-15 years, we report only on simulations covering the 1983-89 period.[27]

For the Base case, oil prices are projected to increase at a 1% yearly rate starting from 1985. These increases are passed on to the domestic economy in the form of higher prices for petroleum products. Food and tree crop prices also increase at a slow rate, while the relative price of services declines. Industrial and electricity prices remain stable. Aggregate investment, government consumption expenditures, and sectoral exports are set at officially forecast levels. Energy supply forecasts also come from

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27 Time and data limitations precluded projection of many exogenous variables beyond 1990.

official plans. Refinery production is expected to peak in 1985 and remain constant thereafter. Significant increases in hydropower capacity have already come on line and more large increases are projected, presumably leading to reduced need for thermal generation. Planned energy sector investment amounts to about one-sixth of total investment in this period, mostly for hydropower projects. About one-third of non-energy investment is allocated to services, one-quarter to services, one-sixth to agriculture, one-tenth each to transport and housing, and the small remainder to tree crops.

The model has been tuned to the base year, 1983, in the sense that it reproduces the base year outcome (Table 1). The parameters of the consumption demand functions were estimated using data from household expenditure surveys. Production function parameters were derived indirectly from input-output data, national accounts, and plan documents. These and other parameters can, and should be, estimated with more care. But, data and time limitations precluded our going farther. For these reasons, it is important to look at these results as tentative, but at the same time indicative of general trends and sensitivities.

The results of the Base case are presented in summary form in Table 4. Values for 1983 and projections for the years 1985, 1987, and 1989 are shown. More detailed projections are contained in the accompanying transactions matrices (Tables 5, 6, and 7). The transactions matrices labeled "at base year prices" represents quantity changes only. The other transactions matrix for each year is labeled "at producers' prices" and the values shown are the quantities times current prices.[28]

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[28] Current prices refer to the real price changes which occur over time such as increases in oil prices. Inflation itself is not considered.

Table 4: MACROECONOMIC PROJECTIONS
(UNITS: BILLIONS OF 1983 RUPEES)

BASE CASE

	1983	1985	1987	1989	GROWTH RATE 1983-89
PRIVATE CONSUMPTION	94.70	105.41	115.62	123.12	4.5%
PUBLIC CONSUMPTION	9.75	10.96	11.63	12.41	4.1%
GROSS INVESTMENT	35.29	39.16	41.77	46.46	4.7%
EXPORTS	33.80	43.71	49.44	55.80	8.7%
IMPORTS	53.76	63.74	69.70	79.29	6.7%
OIL IMPORTS	7.82	9.74	9.94	10.14	4.4%
TRADE DEFICIT	19.96	20.03	20.25	23.48	2.7%
NET INDIRECT TAXES	5.42	4.98	5.40	6.14	2.1%
GROSS DOMESTIC PRODUCT	114.37	130.53	143.36	152.36	4.9%

ENERGY PRODUCTION AND USAGE
(UNITS: THOUSANDS OF TONS, GWH)

	1983	1985	1987	1989	GROWTH RATE 1983-89
REFINED PRODUCTS	1777	2171	2171	2171	3.4%
-INTERMEDIATE USES	842	837	906	972	2.4%
-FINAL DEMAND	541	678	804	923	9.3%
ELECTRICITY	2114	2334	2473	2586	3.4%
-INTERMEDIATE USE	408	451	514	568	5.7%
-CONSUMPTION USE	1373	1424	1464	1501	1.5%
BIOMASS	3750	3883	4140	4366	2.6%
-INTERMEDIATE USE	1271	1304	1458	1591	3.8%
-CONSUMPTION USE	2479	2579	2682	2775	1.9%

SECTORAL GROSS OUTPUT
(UNITS: BILLIONS OF 1983 RUPEES)

SECTORS	1983	1985	1987	1989	GROWTH RATE 1983-89
PADDY AGRICULTURE	28.21	29.14	30.09	30.96	1.6%
TREE CROPS	19.83	21.17	23.01	24.93	3.9%
INDUSTRY	52.49	60.09	67.83	74.92	6.1%
TRANSPORTATION	18.11	19.67	20.79	21.88	3.2%
HOUSING	4.12	4.51	4.88	5.22	4.0%
SERVICES	43.52	51.25	58.27	63.72	6.6%
REFINED PETROLEUM	8.41	10.28	10.28	10.28	3.4%
ELECTRICITY	4.88	5.38	5.71	5.97	3.4%

The top part of Table 4 summarizes the path of the macroeconomic variables at producer prices. In most respects this is an optimistic scenario. GDP increases at almost 5% per year. Domestic absorption grows a little more slowly as the trade deficit declines moderately as a share of GDP. However, these results pointed up some inconsistency between the official projections of aggregate growth, investment, and the trade deficit. In the Base case, the trade deficit grows at almost 3% yearly, while the official forecast is for a decline. The model indicates that one of the targets will have to be modified.[29] This is a good example of how the model can be used in investigating the internal consistency of the many independent forecasts which typically enter a medium term macro forecast.

The fastest growing sectors are services and industry, both increasing in excess of 6% annually. Agriculture and transportation increase at a slower rate than might be expected. This is probably due to their comparatively small shares in the investment allocation plan. This, in turn, suggests the utility of further experimentation with sectoral investment plans, as well as with the production function parameters themselves.

The energy projections also appear favorable. Total energy usage (aggregated at base year prices) increases at only 1.6% annually, which is only one-third the rate of increase in real GDP.[30] Several factors account for this low rate of energy demand growth. The most important single factor has to do with the demand for refined petroleum products by the electricity sector. As new hydropower capacity comes on line, the need to use petroleum

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[29] We should add, however, that if Sri Lanka does achieve a 5% aggregate growth rate, trade deficits on the order of those in this case would probably not be difficult to finance.

[30] This can be calculated by comparing the transactions matrix for 1989 (Table 7) with the transactions matrix for 1983 (Table 1).

TABLE 5: 1985 TRANSACTIONS MATRIX AT BASE YEAR PRICES
BASE CASE

(UNITS: BILLIONS OF 1983 RUPEES)

SECTORS	PADDY AGRIC	TREE CROPS	INDUSTRY	TRANS-PORT	HOUSE-ING	SERVICES	PETROL PRODS	ELEC-TRIC	BIO-MASS	TOTAL INTERMED DELIV.	PRIVATE CONS.	PUBLIC CONS.	GROSS INVEST.	NET TRADE	TOTAL FINAL DEMAND
DDY AGRICULTURE	1.515	0.123	9.465	0.000	0.000	0.026	0.000	0.000	0.000	11.129	23.388	0.204	0.000	-5.579	18.013
EE CROPS	0.000	6.449	0.601	0.000	0.000	0.000	0.000	0.000	0.000	7.050	2.885	0.000	0.000	11.236	14.121
DUSTRY	2.830	1.772	7.812	0.567	0.409	1.891	0.008	0.351	0.000	15.640	28.449	1.864	16.449	-2.308	44.455
ANSPORTATION	0.420	0.163	3.323	0.746	0.056	0.446	0.290	0.135	0.000	5.578	12.936	1.154	0.000	-0.007	14.093
USING	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.494	0.000	0.000	0.012	4.506
RVICES	0.924	0.167	7.764	1.753	0.128	2.824	0.146	0.188	0.000	13.904	25.554	5.712	0.000	5.085	37.350
FINED PETROLEUM	0.000	0.084	0.566	2.893	0.000	0.338	0.084	0.193	0.000	4.158	2.674	0.537	0.000	2.910	6.121
ECTRICITY	0.015	0.006	0.503	0.018	0.000	0.497	0.001	1.059	0.000	2.099	2.846	0.439	0.000	0.000	3.285
N-COMP. IMPORTS	0.125	0.080	0.829	1.702	0.000	0.256	0.004	0.162	0.000	3.158	0.000	1.316	22.715	-27.190	-3.158
UDE OIL	0.000	0.000	0.000	0.000	0.000	0.000	9.551	0.000	0.000	9.551	0.000	0.000	0.000	-9.551	-9.551
OMASS	0.000	0.340	0.284	0.000	0.000	0.133	0.000	0.000	0.000	0.757	1.497	0.000	0.000	0.000	1.497
TAL INTERMEDIAT	5.828	9.184	31.147	7.677	0.592	6.422	10.085	2.088	0.000	73.024	104.723	11.234	39.165	-24.392	130.730
LUE ADDED	23.314	11.987	28.947	11.994	3.913	44.832	0.194	3.296	2.253	130.730					
WAGE INCOME	23.314	9.297	14.026	2.884	0.000	12.014	0.108	0.298	2.253	64.193					
PROFIT INCOME	0.000	2.690	14.921	9.110	3.913	32.818	0.086	2.998	0.000	66.537					
OSS OUTPUT	29.142	21.171	60.095	19.671	4.506	51.254	10.279	5.384	2.253	203.754					

1985 TRANSACTIONS MATRIX AT PRODUCERS PRICES
(UNITS: BILLIONS OF 1983 RUPEES)

SECTORS	PADDY AGRIC	TREE CROPS	INDUSTRY	TRANS-PORT	HOUSE-ING	SERVICES	PETROL PRODS	ELEC-TRIC	BIO-MASS	TOTAL INTERMED DELIV.	PRIVATE CONS.	PUBLIC CONS.	GROSS INV.	NET MKT PRICE TRADE	TOTAL FINAL DEMAND	BORDE PRICE TRADE
DDY AGRIC.	1.628	0.132	10.165	0.000	0.000	0.028	0.000	0.000	0.000	11.952	25.119	0.219	0.000	-5.992	19.346	-5.99
EE CROPS	0.000	6.545	0.610	0.000	0.000	0.000	0.000	0.000	0.000	7.155	2.928	0.000	0.000	11.405	14.333	14.25
DUSTRY	2.830	1.772	7.812	0.567	0.409	1.891	0.008	0.351	0.000	15.640	28.449	1.864	16.449	-2.308	44.455	-1.84
ANSPORTATION	0.395	0.154	3.130	0.702	0.053	0.420	0.273	0.127	0.000	5.254	12.186	1.097	0.000	-0.007	13.276	0.02
USING	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.064	0.000	0.000	0.013	5.078	0.00
RVICES	0.887	0.161	7.454	1.683	0.122	2.721	0.140	0.181	0.000	13.348	24.532	5.482	0.000	5.842	35.856	5.84
FINED PET.	0.000	0.086	0.578	2.954	0.000	0.345	0.086	0.197	0.000	4.246	2.730	0.548	0.000	2.971	6.249	2.16
ECTRICITY	0.015	0.006	0.503	0.018	0.000	0.497	0.001	1.059	0.000	2.099	2.846	0.439	0.000	0.000	3.285	0.00
N-COMP. IMP.	0.125	0.080	0.829	1.702	0.000	0.256	0.004	0.162	0.000	3.158	0.000	1.316	22.715	-27.190	-3.158	-24.71
UDE OIL	0.000	0.000	0.000	0.000	0.000	0.000	9.743	0.000	0.000	9.743	0.000	0.000	0.000	-9.743	-9.743	-9.74
OMASS	0.000	0.353	0.295	0.000	0.000	0.139	0.000	0.000	0.000	0.788	1.558	0.000	0.000	0.000	1.558	0.00
TAL INTERMED.	5.879	9.289	31.377	7.624	0.584	6.297	10.255	2.077	0.000	73.383	105.413	10.964	39.165	-25.008	130.534	-22.02
LUE ADDED	25.419	12.199	28.718	10.906	4.494	42.907	0.240	3.307	2.345	130.534	2.001	0.000	0.000	0.000	2.001	IND. T
WAGE INCOME	25.419	9.297	14.026	2.884	0.000	12.014	0.108	0.298	2.345	66.391	107.414	10.964	39.165	-25.008	132.536	TOTAL
PROFIT INCOME	0.000	2.902	14.692	8.022	4.494	30.893	0.132	3.009	0.000	64.143						
OSS OUTPUT	31.298	21.488	60.095	18.530	5.078	49.204	10.495	5.384	2.345	203.917						

TABLE 6: 1987 TRANSACTIONS MATRIX AT BASE YEAR PRICES
BASE CASE

(UNITS: BILLIONS OF 1983 RUPEES)

SECTORS	PADDY AGRIC	TREE CROPS	INDUSTRY	TRANS-PORT	HOUSE-ING	SERVICES	PETROL PRODS	ELEC-TRIC	BIO-MASS	TOTAL INTERMED DELIV.	PRIVATE CONS.	PUBLIC CONS.	GROSS INVEST.	NET TRADE	TOTAL FINAL DEMAND
IDDY AGRICULTURE	1.565	0.133	10.683	0.000	0.000	0.029	0.000	0.000	0.000	12.410	26.005	0.212	0.000	-8.537	17.680
EE CROPS	0.000	7.008	0.678	0.000	0.000	0.000	0.000	0.000	0.000	7.687	3.148	0.000	0.000	12.174	15.322
IDUSTRY	2.922	1.926	8.818	0.599	0.443	2.150	0.008	0.342	0.000	17.208	32.214	1.977	17.542	-1.112	50.621
ANSPORTATION	0.433	0.177	3.751	0.788	0.061	0.507	0.290	0.143	0.000	6.149	13.454	1.197	0.000	-0.008	14.643
IUSING	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.881	0.000	0.000	-0.001	4.881
RVICES	0.954	0.182	8.763	1.853	0.138	3.222	0.146	0.200	0.200	15.458	26.754	6.306	0.000	9.748	42.808
FINED PETROLEUM	0.000	0.092	0.656	3.076	0.000	0.385	0.084	0.000	0.000	4.292	3.250	0.558	0.000	2.179	5.987
ECTRICITY	0.015	0.007	0.579	0.019	0.000	0.565	0.001	1.141	0.000	2.327	2.913	0.465	0.000	0.300	3.378
N-COMP. IMPORTS	0.129	0.087	0.936	1.799	0.000	0.291	0.004	0.171	0.000	3.418	0.000	1.396	24.225	-29.039	-3.418
UDE OIL	0.000	0.000	0.000	0.000	0.000	0.000	9.552	0.000	0.000	9.552	0.000	0.000	0.000	-9.552	-9.552
OMASS	0.000	0.368	0.327	0.000	0.000	0.151	0.000	0.000	0.000	0.846	1.556	0.000	0.000	0.002	1.556
ITAL INTERMEDIAT	6.018	9.980	35.191	8.132	0.642	7.301	10.085	1.997	0.000	79.347	114.177	12.111	41.767	-24.147	143.908
ILUE ADDED	24.072	13.028	32.637	12.660	4.239	50.965	0.194	3.708	2.402	143.908					
WAGE INCOME	24.072	10.209	15.863	3.048	0.000	13.063	0.108	0.311	2.402	69.077					
PROFIT INCOME	0.000	2.820	16.774	9.612	4.239	37.902	0.086	3.398	0.000	74.831					
IOSS OUTPUT	30.091	23.009	67.829	20.793	4.881	58.266	10.280	5.705	2.402	223.255					

1987 TRANSACTIONS MATRIX AT PRODUCERS PRICES

(UNITS: BILLIONS OF 1983 RUPEES)

SECTORS	PADDY AGRIC	TREE CROPS	INDUSTRY	TRANS-PORT	HOUSE-ING	SERVICES	PETROL PRODS	ELEC-TRIC	BIO-MASS	TOTAL INTERMED DELIV.	PRIVATE CONS.	PUBLIC CONS.	GROSS INV.	NET MKT PRICE TRADE	TOTAL FINAL DEMAND	BORDE PRICE TRADE
IDDY AGRIC.	1.713	0.146	11.698	0.000	0.000	0.032	0.000	0.000	0.000	13.589	28.475	0.233	0.000	-9.348	19.360	-9.34
EE CROPS	0.000	7.219	0.699	0.000	0.000	0.000	0.000	0.000	0.000	7.917	3.243	0.000	0.000	12.539	15.782	15.68
IDUSTRY	2.922	1.926	8.818	0.599	0.443	2.150	0.008	0.342	0.000	17.208	32.214	1.977	17.542	-1.112	50.621	-0.89
IANSPORTATION	0.421	0.172	3.646	0.766	0.059	0.493	0.282	0.139	0.000	5.977	13.078	1.163	0.000	-0.007	14.233	0.00
IUSING	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.960	0.000	0.000	-0.001	5.959	0.00
RVICES	0.879	0.168	8.080	1.708	0.127	2.971	0.135	0.184	0.000	14.252	24.668	5.814	0.000	8.988	39.469	8.98
FINED PET.	0.000	0.095	0.683	3.202	0.000	0.400	0.088	0.000	0.000	4.468	3.383	0.581	0.000	2.268	6.233	1.65
ECTRICITY	0.015	0.007	0.579	0.019	0.000	0.565	0.001	1.141	0.000	2.327	2.913	0.465	0.000	0.000	3.378	0.00
IN-COMP. IMP.	0.129	0.087	0.936	1.799	0.000	0.291	0.004	0.171	0.000	3.418	0.000	1.396	24.225	-29.039	-3.418	-26.39
IUDE OIL	0.000	0.000	0.000	0.000	0.000	0.000	9.943	0.000	0.000	9.943	0.000	0.000	0.000	-9.943	-9.943	-9.94
OMASS	0.000	0.398	0.354	0.000	0.000	0.164	0.000	0.000	0.000	0.916	1.685	0.000	0.000	0.000	1.685	0.00
ITAL INTERMED.	6.080	10.218	35.492	8.092	0.629	7.066	10.461	1.977	0.000	80.017	115.619	11.629	41.767	-25.655	143.360	-20.25
ILUE ADDED	26.869	13.480	32.336	12.119	5.330	46.655	0.240	3.728	2.602	143.359	2.136	0.000	0.000	0.000	2.136	IND. T
WAGE INCOME	26.869	10.209	15.863	3.048	0.000	13.063	0.108	0.311	2.602	72.072	117.755	11.629	41.767	-25.655	145.496	TOTAL
PROFIT INCOME	0.000	3.272	16.474	9.070	5.330	33.592	0.132	3.417	0.000	71.287						
IOSS OUTPUT	32.949	23.699	67.829	20.211	5.959	53.721	10.701	5.705	2.602	223.376						

TABLE 7: 1989 TRANSACTIONS MATRIX AT BASE YEAR PRICES
BASE CASE

(UNITS: BILLIONS OF 1983 RUPEES)

SECTORS	PADDY AGRIC	TREE CROPS	INDUSTRY	TRANS- PORT	HOUSE- ING	SERVICES	PETROL PRODS	ELEC- TRIC	BIO- MASS	TOTAL INTERMED DELIV.	PRIVATE CONS.	PUBLIC CONS.	GROSS INVEST.	NET TRADE	TOTAL FINAL DEMAND
DDY AGRICULTURE	1.610	0.145	11.800	0.000	0.000	0.032	0.000	0.000	0.000	13.586	28.010	0.222	0.000	-10.856	17.377
EE CROPS	0.000	7.592	0.749	0.000	0.000	0.000	0.000	0.000	0.000	8.341	3.355	0.000	0.000	13.229	16.584
DUSTRY	3.006	2.086	9.739	0.630	0.474	2.351	0.008	0.358	0.000	18.654	35.266	2.109	19.513	-0.623	56.264
ANSPORTATION	0.446	0.192	4.143	0.829	0.065	0.554	0.290	0.149	0.000	6.668	13.924	1.275	0.000	0.008	15.208
USING	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.236	0.000	0.000	-0.014	5.222
RVICES	0.982	0.197	9.679	1.949	0.148	3.524	0.146	0.209	0.000	16.833	27.972	7.163	0.000	11.753	46.888
FINED PETROLEUM	0.000	0.099	0.740	3.258	0.000	0.421	0.084	0.000	0.000	4.602	3.770	0.600	0.000	1.308	5.677
ECTRICITY	0.015	0.007	0.649	0.020	0.000	0.618	0.001	1.193	0.000	2.504	2.967	0.496	0.000	0.000	3.463
N-COMP. IMPORTS	0.133	0.095	1.034	1.892	0.000	0.319	0.004	0.179	0.000	3.656	0.000	1.489	26.946	-32.091	-3.656
UDE OIL	0.000	0.000	0.000	0.000	0.000	0.000	9.551	0.000	0.000	9.551	0.000	0.000	0.000	-9.551	-9.551
OMASS	0.000	0.393	0.364	0.000	0.000	0.166	0.000	0.000	0.000	0.923	1.610	0.000	0.000	0.000	1.610
TAL INTERMEDIAT	6.193	10.806	38.898	8.578	0.687	7.984	10.085	2.088	0.000	85.319	122.110	13.355	46.459	-26.837	155.087
LUE ADDED	24.770	14.119	36.021	13.298	4.536	55.737	0.194	3.878	2.533	155.087					
WAGE INCOME	24.770	11.186	17.560	3.207	0.000	13.341	0.108	0.324	2.533	73.030					
PROFIT INCOME	0.000	2.933	18.461	10.091	4.536	42.396	0.086	3.554	0.000	82.057					
OSS OUTPUT	30.963	24.926	74.918	21.876	5.222	63.722	10.279	5.966	2.533	240.406					

1989 TRANSACTIONS MATRIX AT PRODUCERS PRICES

(UNITS: BILLIONS OF 1983 RUPEES)

SECTORS	PADDY AGRIC	TREE CROPS	INDUSTRY	TRANS- PORT	HOUSE- ING	SERVICES	PETROL PRODS	ELEC- TRIC	BIO- MASS	TOTAL INTERMED DELIV.	PRIVATE CONS.	PUBLIC CONS.	GROSS INV.	NET MKT PRICE TRADE	TOTAL FINAL DEMAND	BORDE PRICE TRADE
DDY AGRIC.	1.798	0.161	13.180	0.000	0.000	0.036	0.000	0.000	0.000	15.176	31.288	0.248	0.000	-12.126	19.410	-12.12
EE CROPS	0.000	7.942	0.784	0.000	0.000	0.000	0.000	0.000	0.000	8.725	3.509	0.000	0.000	13.838	17.347	17.29
DUSTRY	3.006	2.086	9.739	0.630	0.474	2.351	0.008	0.358	0.000	18.654	35.266	2.109	19.513	-0.623	56.264	-0.49
ANSPORTATION	0.434	0.187	4.031	0.807	0.063	0.539	0.282	0.145	0.000	6.488	13.548	1.241	0.000	0.008	14.797	0.00
USING	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6.608	0.000	0.000	-0.018	6.591	0.00
RVICES	0.850	0.171	8.382	1.688	0.128	3.052	0.126	0.181	0.000	14.578	24.224	6.203	0.000	10.178	40.605	10.17
FINED PET.	0.000	0.102	0.765	3.369	0.000	0.435	0.087	0.000	0.000	4.758	3.898	0.620	0.000	1.352	5.871	0.98
ECTRICITY	0.015	0.007	0.649	0.020	0.000	0.618	0.001	1.193	0.000	2.504	2.967	0.496	0.000	0.000	3.463	0.00
N-COMP. IMP.	0.133	0.095	1.034	1.892	0.000	0.319	0.004	0.179	0.000	3.656	0.000	1.489	26.946	-32.091	-3.656	-29.17
UDE OIL	0.000	0.000	0.000	0.000	0.000	0.000	10.144	0.000	0.000	10.144	0.000	0.000	0.000	-10.144	-10.144	-10.14
OMASS	0.000	0.443	0.411	0.000	0.000	0.187	0.000	0.000	0.000	1.041	1.814	0.000	0.000	0.000	1.814	0.00
TAL INTERMED.	6.237	11.194	38.975	8.405	0.665	7.536	10.653	2.056	0.000	85.722	123.122	12.407	46.459	-29.625	152.363	-23.48
LUE ADDED	28.348	14.878	35.943	12.880	5.926	47.647	-0.024	3.910	2.855	152.363	2.179	0.000	0.000	0.000	2.179	IND. T
WAGE INCOME	28.348	11.186	17.560	3.207	0.000	13.341	0.108	0.324	2.855	76.930	125.300	12.407	46.459	-29.625	154.542	TOTAL
PROFIT INCOME	0.000	3.692	18.383	9.673	5.926	34.306	-0.132	3.586	0.000	75.433						
OSS OUTPUT	34.585	26.072	74.918	21.285	6.591	55.183	10.629	5.966	2.855	238.085						

products for thermal generation declines rapidly, and is nothing after 1986.[31] Since this intermediate energy demand accounted for 26% of all domestic demand for refined products in 1983 the impact is considerable. In fact, total domestic demand for petroleum products is projected to decline somewhat until 1989. Looking at Tables 1 and 6, if only the growth in non-energy demand for energy is considered, the rate increases to 4.2% or 85% of GDP growth.

Prices play an important role. The costs to producers of petroleum products and biomass rises steadily, and, since the sectoral demand curves for these goods is price sensitive, less is demanded per unit of output. The middle section of Table 4 shows this.[32] Here intermediate demand for energy includes only the non-energy sectors. Intermediate demand for electricity, whose price remains constant, increases at about the same rate as the average of the sectoral gross output growth rates which are shown in the bottom of Table 4. Demand for fuels increases at about half that rate. Another important factor is the sectoral composition of output. In this scenario, transportation grows slower than the economy as a whole. Since this is the largest sectoral user of energy the impact is significant.

For private consumption, the picture is somewhat blurred. Demand for petroleum products grows faster than aggregate consumption. Apparently, the effects of the high estimated income income elasticity outweighs the price elasticity effects. Household demand for electricity increases very slowly. This is due largely to the low income elasticity which was used, suggesting

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31 This can be seen in Table 6. Purchases of petroleum products by the electricity sector are zero in 1987, indicating that there is no longer any need for thermal generation.

32 For this table, "intermediate uses" includes only non-energy sector demand. The refined products row is actual domestic production. The difference between this and the sum of intermediate uses and final demand is electricity demand and net trade. For electricity, the difference between generation and deliveries to non-energy sectors is due almost entirely to transmission and distribution losses.

that this parameter be re-estimated. The cross-price elasticity of electricity with respect to other energy prices may be negative, which would further dampen demand growth.

Electricity demand in this scenario grows at a lower rate than hydropower capacity. One implication is that medium term investment strategy might put greater emphasis on projects which can make economic use of this potential capacity. As demand for fuels for electric power generation declines, refinery capacity becomes greater than total domestic demand and the model disposes of the surplus through exports. Combining crude oil imports (shown in Table 4) with product trade (shown in the transactions tables), demand for imported fuels increases at 1% a year and total import costs at 2%. Thus energy import costs, while not insignificant, do not account for a very large proportion of the total import bill or the trade deficit.[33]

The exogenous assumptions for Cases 2 and 3 are same as those used for the Base case, except for crude oil and petroleum product prices. The alternative cases test the impact of a moderate rise in world prices. Instead of the 1% increase in the Base case, these prices are projected to increase at 5% annually. The trade deficit is held at the same levels as in Base case, implying that adjustments must be made in investment to maintain consistency. In Case 2, domestic petroleum product prices are increase at only 1% a year, the Base case assumption, indicating that the increases in international prices are not passed through. The domestic economy, therefore does not see the changing relative price picture and does not adjust downward either the petroleum-output ratios or the share of household consumption spent on energy.

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33 Of course, other scenarios (including those which allocate more investment to transportation) might lead to much more rapid growth in petroleum product demand and import costs.

TABLE 8: MACROECONOMIC PROJECTIONS
(UNITS: BILLIONS OF 1983 RUPEES)

HIGHER WORLD, CONSTANT DOMESTIC OIL PRICES--TRADE DEFICIT PREDETERMINED

	1983	1985	1987	1989	GROWTH RATE 1983-89
PRIVATE CONSUMPTION	94.70	105.35	115.25	122.15	4.3%
PUBLIC CONSUMPTION	9.75	10.96	11.63	12.41	4.1%
GROSS INVESTMENT	35.29	38.96	41.10	45.44	4.3%
EXPORTS	33.80	43.86	49.97	57.01	9.1%
IMPORTS	53.76	63.88	70.23	80.51	7.0%
OIL IMPORTS	7.82	10.12	11.17	12.31	7.9%
TRADE DEFICIT	19.96	20.02	20.25	23.51	2.8%
NET INDIRECT TAXES	5.42	4.93	5.21	5.72	0.9%
GROSS DOMESTIC PRODUCT	114.37	130.32	142.51	150.77	4.7%

ENERGY PRODUCTION AND USAGE
(UNITS: THOUSANDS OF TONS, GWH)

	1983	1985	1987	1989	GROWTH RATE 1983-89
REFINED PRODUCTS	1777	2171	2171	2171	3.4%
-INTERMEDIATE USES	842	836	896	945	2.0%
-FINAL DEMAND	541	660	737	771	6.1%
ELECTRICITY	2114	2333	2470	2577	3.4%
-INTERMEDIATE USE	408	451	513	564	5.5%
-CONSUMPTION USE	1373	1424	1463	1497	1.5%
BIOMASS	3750	3884	4144	4373	2.6%
-INTERMEDIATE USE	1271	1305	1464	1603	3.9%
-CONSUMPTION USE	2479	2579	2680	2770	1.9%

SECTORAL GROSS OUTPUT
(UNITS: BILLIONS OF 1983 RUPEES)

SECTORS	1983	1985	1987	1989	GROWTH RATE 1983-89
PADDY AGRICULTURE	28.21	29.14	30.05	30.84	1.5%
TREE CROPS	19.83	21.17	22.97	24.78	3.8%
INDUSTRY	52.49	60.09	67.69	74.42	6.0%
TRANSPORTATION	18.11	19.66	20.70	21.61	3.0%
HOUSING	4.12	4.51	4.87	5.20	4.0%
SERVICES	43.52	51.25	58.13	63.26	6.4%
REFINED PETROLEUM	8.41	10.28	10.28	10.28	3.4%
ELECTRICITY	4.88	5.38	5.70	5.94	3.4%

Summary results for Case 2 are presented in Table 8. Through 1989, the macroeconomic projections are not very different from the Base case. This is because the price increases do not start until 1985 and their effect is gradual. GDP growth is about 10% less during the last half of this period. The impact on investment, as expected, is somewhat greater. Investment growth by the late 1980s is about 20% less than previously.

Even though prices do not change, domestic demand for petroleum products about about 10% lower by 1989 than in the Base case. Most of this reduction is due to slower growth of consumption, which when combined with an income elasticity of demand in excess of unity, leads to substantial fall-off in demand growth. Intermediate demand growth falls at the same rate as sectoral production since prices are unchanged. The increase in crude oil import costs is partially offset by increased product exports due to reduced domestic demand. The net effect is a 13% increase in the total costs of imported fuels in 1989 when compared with the Base case. Again, the effects would be more substantial if transportation grew at a faster rate. In any case, since the price increase is gradual and the full adjustments on the production side to higher energy costs occur with long lags, the effects can be expected to be very substantial during the 1990s.[34]

The only difference between Cases 2 and 3 is that the latter assumes that the higher border prices for petroleum products are passed on to domestic users. The effect of this policy should be a reduction in sectoral petroleum product-gross output ratios and in household demand for these products (per unit of total expenditure. These changes lead to lower fuel demand which should free additional resources for investment. The model captures these

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[34] This strongly suggests that to make full use of the model, a longer time horizon should be utilized.

TABLE 9: MACROECONOMIC PROJECTIONS
(UNITS: BILLIONS OF 1983 RUPEES)

HIGHER WORLD OIL PRICES--TRADE DEFICIT PREDETERMINED

	1983	1985	1987	1989	GROWTH RATE 1983-89
PRIVATE CONSUMPTION	94.70	105.32	115.27	122.27	4.4%
PUBLIC CONSUMPTION	9.75	10.96	11.63	12.41	4.1%
GROSS INVESTMENT	35.29	39.04	41.41	46.02	4.5%
EXPORTS	33.80	43.86	49.97	57.01	9.1%
IMPORTS	53.76	63.89	70.24	80.50	7.0%
OIL IMPORTS	7.82	10.12	11.17	12.31	7.9%
TRADE DEFICIT	19.96	20.03	20.26	23.50	2.8%
NET INDIRECT TAXES	5.42	4.88	5.07	5.54	0.4%
GROSS DOMESTIC PRODUCT	114.37	130.42	142.96	151.66	4.8%

ENERGY PRODUCTION AND USAGE
(UNITS: THOUSANDS OF TONS, GWH)

	1983	1985	1987	1989	GROWTH RATE 1983-89
REFINED PRODUCTS	1777	2171	2171	2171	3.4%
-INTERMEDIATE USES	842	835	893	938	1.8%
-FINAL DEMAND	541	651	709	726	5.0%
ELECTRICITY	2114	2333	2470	2578	3.4%
-INTERMEDIATE USE	408	451	513	565	5.6%
-CONSUMPTION USE	1373	1423	1463	1497	1.5%
BIOMASS	3750	3884	4149	4387	2.6%
-INTERMEDIATE USE	1271	1306	1469	1616	4.1%
-CONSUMPTION USE	2479	2579	2680	2770	1.9%

SECTORAL GROSS OUTPUT
(UNITS: BILLIONS OF 1983 RUPEES)

SECTORS	1983	1985	1987	1989	GROWTH RATE 1983-89
PADDY AGRICULTURE	28.21	29.14	30.07	30.89	1.5%
TREE CROPS	19.83	21.17	22.98	24.84	3.8%
INDUSTRY	52.49	60.09	67.73	74.59	6.0%
TRANSPORTATION	18.11	19.65	20.68	21.58	3.0%
HOUSING	4.12	4.51	4.88	5.21	4.0%
SERVICES	43.52	51.25	58.17	63.42	6.5%
REFINED PETROLEUM	8.41	10.28	10.28	10.28	3.4%
ELECTRICITY	4.88	5.38	5.70	5.95	3.4%

effects, as well as the positive feedback of greater investment on production and income. These second round effects will tend to push energy demand back up.

Table 9 summarizes the projections for Case 3. Although the differences are not too large in absolute terms, the results clearly illustrate how the price mechanism works. Aggregate economic growth is about in the middle of the results for the Base case and Case 2. The most significant macroeconomic result is that investment levels are only slightly lower than in the Base case. This is what permits faster growth than in Case 2, despite the decline in the endogenous output-capital ratios due to higher energy costs.

Tables 8 and 9 demonstrate the impact of changing energy prices on demand. Total gross output in the non-energy sectors is 3% higher by 1989 in Case 3, but intermediate demand for petroleum products actually falls by 1%. Household demand for petroleum products declines 5%, with aggregate consumption unchanged. The net effect on the costs of imported fuels is a 2% reduction by 1989. These results provide a general equilibrium rationale for passing future price changes through to the economy. Whatever direct losses there are due to higher costs for producers and households are quickly made up for in terms of greater growth of production and real income than would otherwise be possible. These positive effects would show up more dramatically as the model looks farther into the future.

V. Conclusions

The interrelations between energy issues and general development problems and policies are complex and the analysis which deals with such interrelationships should take into account the essential features of that complexity. The interactions between energy policies and other features of an economy must certainly be one of those essential features. The relationships are seldom, if ever, one way, from energy policies to the rest of the economy or from economic influences to energy issues.

The major approaches to energy policy analysis have been reviewed here: project evaluation, technology assessment, energy sector assessment, macro simulation models, economy-wide optimization models and computable general equilibrium models. Each of these approaches has certain strengths which make it useful in particular applications. Problems arise when the methods are applied to problems for which they are inadequate or in circumstances in which they are unwieldy, if not infeasible. In principle, all of the approaches, except the first and the last two suffer from two major deficiencies. First, they are partial in nature, i.e. they take into account only one or a few relations between energy and economic issues. Second, the relationships which they embody are one-way, from energy to the economy, or vice-versa, but not back and forth.

The use of correctly estimated shadow prices in project evaluation can, in principle, resolve these deficiencies. The difficulty in making the principle into a practical tool is in estimating shadow prices, not just for energy in various applications, but for all the other changes which reverberate through an economy. When an energy project is small, relative to the economy as a whole, those reverberations will also be small and can be expected to be dampened relatively quickly. When a project or policy is large, or has an sector-wide or economy-wide scope, project evaluation is, at best, unwieldy or at worst, infeasible. If it can be implemented at all, in such circumstances, project evaluation essentially turns into one of the two last approaches mentioned above: economy-wide optimization models or computable general equilibrium models.

These latter models are general in scope and do take into account energy-economy interactions. While they can become complex, in terms of the number of features which they contain, each one of those features reflects a rather standard aspect of conventional microeconomic analysis and can be made readily understandable. Each approach has certain advantages and disadvantages The economy-wide optimization models treat intertemporal issues in a more satisfactory manner but are unwieldy in analyzing price, tax and subsidy question. The computable general equilibrium models are better with the latter type of issues but are myopic in their intertemporal analysis. Yet both types of models are general in scope and take energy-economy interactions fully into account.

The difficulties associated with these latter two types of models have to do with the demands which they make for data, time and resources of expertise and computational capabilities. These difficulties were the inspiration for the particular model developed here, which is a simple intertemporal version of a computable general equilibrium model. We have demonstrated the feasibility of constructing such a model rather quickly, with a quite limited budget and with data no better than in many developing countries by actually creating and applying the model to the Sri Lankan economy under these constraints. Three alternative solutions are provided to demonstrate the potential of the model.

The test of the Sri Lankan model is not only in its formulation and embodiment with data but also in the insights which it can provide. The three alternative solutions presented are intended to illustrate such insights and should not be interpreted as being definitive. The base case solution demonstrates the interrelationships in the economy and raises a number of questions. One of these, for example, is related to the consistency of the official forecast or plan. That projects a decline in the trade deficit while the model forecasts an increase, when all the other conditions of the official forecast are embodied. Since there are some questions of interpretation which could not be resolved, this result should not be taken as a definitive criticism but, rather, intended only as an illustration of a potential application.

In the second application the effects of a significant increase in international oil prices are analysed under the assumption that the price increase is not passed on to the domestic economy. Even so, the constraint on the trade deficit leads to a reduction in domestic income and, consequently, in energy and other types of consumption. In the third application, the assumed increase in energy prices are passed on to the domestic economy and the contractionary effects of the price increase become even more pronounced.

The qualitative character of these last results could be deduced without going to the trouble of constructing this or any other type of quantitative model. But only a model such as this could give assurance that quantitative estimates of the implications of policies and shocks were estimated with a technique whose essential features matched the character of the real interactions in the economy.

Finally, it should be noted that, while there are no deep mysteries involved in the construction of a model of the type presented, neither is the exercise an obvious one. The first time is the hardest, however, and practice, if it will never achieve perfection, will, at least, quicken and improve the approximation.

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