Simulation of Macroeconomic Scenarios to Assess the Energy Demand for India (SIMA)

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FOREWORD

The Energy Systems Program (ENP) at the International Institute for Applied Systems Analysis (IIASA) has developed a set of models giving coverage of energy and energy-related issues for macroregions of the world over the long term (50 to 60 years). The SIMA model, a macroeconomic simulation model to assess energy demand for India, is included in this larger effort, which has been partially supported by a grant from the United Nations Environment Programme (UNEP).

The use of the SIMA model within the energy modeling effort at IIASA reflects the desire to treat the special considerations of developing regions with as much care as possible. In particular, the treatment of the economic profile and prospects of one developing country with this econometric model can lead towards a greater understanding of energy requirements in the face of alternative economic scenarios. The alternative paths selected for use with the SIMA model included a greater intensification of agriculture, increasing aid, and stepped-up investments and exports (to generate high economic growth). The SIMA model focuses on the central issues of capital availability and sources of export earnings for building up the domestic energy sector. Also considered explicitly are the uses of noncommercial energy and the extent and pace of rural electrification characteristic of developing economies.

Further studies that deal with energy problems in developing countries have been and are being carried out at IIASA, in no small part initiated by the SIMA work.

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CONTENTS

1 INTRODUCTION

This study forms a part of the global modeling exercise of IIASA's Energy Systems Program (ENP). The aim of the ENP effort, in which the world is considered to consist of seven "regions" (Häfele and Basile, 1978), is to evaluate for each region the alternative energy supply strategies consistent with economic scenarios. The ENP defines a world region as a group of countries sharing similar economic features. For this purpose a set of models has been developed, and the models are to be run for each region in the following stages

- Generation of a macroeconomic growth scenario
- Generation of energy demand scenarios consistent with this macroeconomic framework
- Determination of the optimal energy supply mix to meet the energy demand, and consideration of choices of fuel substitution
- Analysis of the impacts on the economy of the selected energy supply mix
- Revision of the macroeconomic framework, if necessary, and iteration of the results of each world region
- Analysis of the global issues concerning energy use and supply

Of the seven regions, four are developing regions, one of which comprises Africa and South and Southeast Asia (excluding Northern Africa, South Africa, Japan, and Asian countries with centrally planned economies).

GENERAL CHARACTERISTICS OF THE AFRICA AND SOUTH AND SOUTHEAST ASIA REGION

Of the main characteristics of the Africa and South and Southeast Asia region, perhaps the most obvious are those of high population growth and limited energy resources. The other characteristics are

- The economy is supply constrained rather than demand driven.
- Agriculture plays an important part in the economy and has increasing capital requirements.
- Imports and foreign aid are of strategic importance in the economy.
- There is substantial use of noncommercial energy (firewood, agricultural waste, charcoal, and animal dung).
- The price elasticity of energy is low, because the present "subsistence" use is at a base level, offering little scope for reducing energy consumption.
- The extent of electrification in rural areas is low; hence demand is suppressed.
- There is competition among the agricultural and nonagricultural (transport, commerce, industry, and services) sectors of the economy for investment and imports.

India constitutes almost 40 percent of the population and 35 percent of the energy consumption of this region, and can be taken as a country typifying the above regional characteristics. For example, in India

- Agriculture forms 45 percent of the gross national product (GNP).
- Noncommercial energy consumption formed approximately 70 percent of the total (noncommercial plus commercial) energy consumption in 1971.
- Only 25 percent of the villages were supplied with electricity in 1971.
- In 1974, 30 percent of export earnings went towards the purchase of oil; at present the figure has risen to 33 percent.
- In the 5-year plan of 1978–1983, 30 percent of government planned investment has been allocated to the energy sector.

Therefore, to understand the behavior of the energy system of the region and its interdependence on the macroeconomic variables, the case study of India is presented as a first step. For this study we have developed a macroeconomic simulation model to assess the energy demand for India – the SIMA model. This model recognizes and attempts to simulate the main features of developing regions that are described above.

Although detailed models are available for each of the stages described in the introductory paragraph, the SIMA model for developing economies goes through the first two (the generation of a macroeconomic growth scenario and energy demand scenarios) simultaneously, so that the feedback from the energy sector to the economy is accounted for as an approximate measure. This may help in reducing the number of iterations required, by providing a more appropriate macroeconomic basis for the ENP set of models.

The SIMA model is used for a long-term period; the projections extend to the year 2030. However, it should be recognized that, even to plan for the energy sector up to 2000, the model should extend much longer, if only to identify approximate trends beyond the planning horizon. The available fossil fuel reserves may easily last until 2000 and beyond, but it is apparent that a shift in energy policy is desirable over the long term. Therefore, a long-term model of this nature is especially relevant for the developing regions whose energy consumption at present is barely above subsistence level. A stabilization of the energy consumption in these regions cannot be foreseen in the next 50 years, if the regions are expected to develop. Projecting the future for the next 50 years calls for a combination of analysis of the past and assessment of the future course of events; the latter will undoubtedly be affected by the economic policies pursued. To explore the policy choices for the future, one needs a mechanism to determine the implications of a given set of policies, and we have therefore constructed a simulation model, the SIMA model.

A BRIEF SUMMARY OF THE WORK ON ENERGY DEMAND FOR INDIA

Projections of energy demand play a crucial role in energy studies. The strategy of supply and the policies pursued to realize the strategy depend on the level of demand. Prior to running the optimization models investigating energy supply options, which are highly refined, the sophistication of these models has to be matched by the projections of demand that drive them. Some of the conclusions of such models can be sensitive to the level of energy demand in an economy. Thus, in the global modeling exercise of the ENP, considerable emphasis is placed on improving the methodology for projecting energy demand. The macroeconomic simulation model of India presented in this report forms a part of this effort. India is taken as a case study of a developing country and it is hoped that the experience gained from using this model will be useful for building appropriate models for other developing regions.

One of the first exercises of energy demand projection for India was carried out by the Energy Survey Committee of India in 1964. This was based on separate trend projections up to 1980 for the household, agricultural, transport, and industrial sectors; these projections were then combined to obtain the total national energy demand. The fuel mix required for the economy was also identified. This exercise, by establishing a data base and a framework for carrying out studies in energy, made an important contribution to the projection of energy demand. It systematically assessed the use of noncommercial fuels, estimated the efficiency of different fuels for various uses, and initiated the use of coal replacement units based on the efficiency of use as well as on calorific content. The use of such coal replacement units rather than coal equivalent units was considered more appropriate in planning for substitution of fuels, particularly of noncommercial fuels by commercial fuels (electricity, coal, oil, and gas). The values of coal equivalent and replacement units are given in Appendix A.

The Fuel Policy Committee of India extended this approach by carrying out projections up to 1990; they also streamlined the data base up to 1971. The Fuel Policy Committee's demand projections were based on more detailed sectoral energy input coefficients, on material balances, and on an evaluation of fuel substitution possibilities.

Parikh (1976), using a similar approach, extended the demand projections up to 2000. Alternative scenarios and strategies are given and the resource requirements for meeting energy needs are also estimated. However, the implications of these cost projections on the development of the economy and on the demand for energy itself have not been investigated.

Parikh and Shrinivasan (1977) have used a linear programming model, within which parts of the energy demand are endogenized, in order to determine India's food and energy options. Demand in the agricultural and transport sectors is prescribed in terms of the desired output of these sectors, such as tons of food grains, passenger-kilometers, ton-kilometers. The energy demand required to meet these needs depends on the technologies selected and is determined within the model, which covers the period up to 2000. However, the authors do not iterate to see whether the final demand projections need to be modified in the light of the techniques and resource requirements indicated by the model solution.

THE OBJECTIVES

The purpose of this report is to project alternative future energy demand scenarios consistent with economic developments and possible energy supply scenarios. It is also to examine the interaction between the increased costs of energy and economic development, which may be important for developing countries where capital accumulation and imports generally constitute the major constraints on development. (The word "demand" is not used throughout this paper in the conventional economic sense of a quantity price schedule. Instead, it refers to the point of intersection of demand and supply, a sense that has been widely adopted by energy analysts.)

When energy is expensive and requires large resources to develop supplies, fewer resources are available for developing other sectors of the economy. Thus, the demand for energy is affected by and in turn affects the development of the economy. The projection of energy demand should be consistent with the projection of economic growth.

Conventional econometric models (for models of India see the references) are usually built for short-term projections. This makes it possible to use linear approximations for nonlinear relationships, which may be locally adequate. A simulation model for long-term projections requires specifications of relationships that are not necessarily linear. With the rather short time series available for India, it is difficult to explore complex hypotheses, and the model had to be kept simple. Relationships that are usually estimated from short-time-series data need to be examined for their appropriateness for long-term projections. In many cases, one may have to replace such estimated relationships by hypotheses that are theoretically more acceptable and that appeal to common sense. At a couple of places we have done so in our model.

In contrast to models of developed economies, in which growth is demand driven and restricted by the limited labor force and by technological progress, models of developing economies have to concentrate on dealing with the difficulties of expanding energy supply, of accumulating capital, and of having a limited availability of imports. The SIMA model requires relatively few exogenous specifications, and we believe it is suitable for coping with the difficulties mentioned above.

Thus, the purpose of this model-building exercise was to construct a model for India that would account for structural changes in the economy; thus, it is built so as to permit an exploration of the effects of alternative scenarios on economic development and energy demand. The scenarios include

- Different levels of government effort to promote investment
- Different rates of development in the agricultural sector
- Different levels of foreign aid
- Different levels of domestic energy availability

Population growth, the level of urbanization, oil price rises, and the capital costs of energy are specified exogenously in these scenarios.

2 THE MODEL

In the SIMA model, the Indian economy is considered as being mainly composed of two sectors. The three essential features of the model can be summarized as follows:

- The two main sectors are agriculture and nonagriculture; the energy sector forms part of the nonagricultural sector but is driven by both of the main sectors.
- The main sectors are in competition with each other for capital stock.
- Some structural relationships are estimated from time-series (1950–1973) data, and others are estimated from scenario specifications.

In the SIMA model the gross domestic product (GDP) is used in private and public (government) consumption and in investment. Private investment is stimulated by government investment and restricted by savings in the economy. Trade is balanced, but foreign aid increases imports and also promotes public investment.

The implications for energy demand and for capital required in the energy sector are derived from the structure of the GNP that emerges. The capital and import requirements for the energy sector compete with the capital and import requirements for the rest of the economy.

In developing a model for long-term projections, the appropriate level of sectoral detail should be used. Although a model with many sectors may permit incorporation of structural changes in some detail, it increases the problems of uncertainties in technological description, and the final projections may be no more reliable than a model with fewer sectors. Although the SIMA model has only two main sectors, it is able to account for structural changes in the Indian economy; some aspects of these structural changes are characterized by the level of urbanization, whose specification in the model is exogenous.

Since one of the features of the model is that it is a useful means of studying the problems of energy policy, the energy sector has to be described in some detail, and the detailed treatment of the energy sector has to match the detail with which the rest of the economy is described. We have tried to resolve this problem by treating the details of the energy sector as consequences of the growth of the economy. The feedback from the energy sector to the economy, however, is based on more aggregated attributes of the energy sector, i.e., the foreign exchange required to import oil and the total investment required for the growth of the energy sector.

A BROAD OUTLINE OF THE MODEL

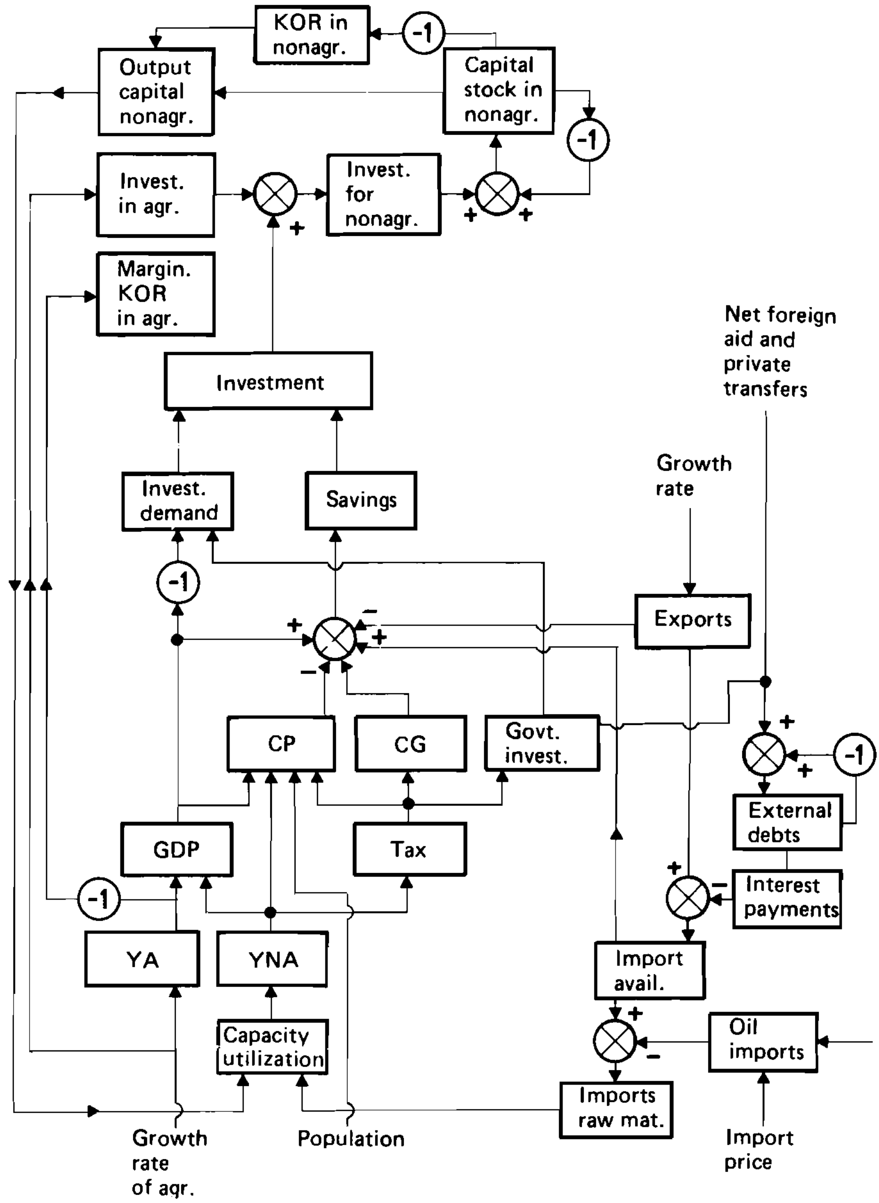
The details of the interactions of the two-sector macroeconomic model can be seen in Figure 1.

The Macroeconomic Module

The GDP is a function of the output of the agricultural and nonagricultural sectors. An exogenously specified growth rate determines the output of the agricultural sector. The output of the nonagricultural sector is determined by the productive capacity created through capital stock accumulation and by the extent to which this capacity can be utilized. Capacity utilization depends on the availability of imports of raw materials, components, and spare parts. The requirements of imports for full capacity utilization depend on the total capital stock and decrease relative to the increase in capital stock, because of the diversification of the economy and import substitution.

Imports are determined by the availability of foreign exchange from net export earnings, by private transfers (from Indians residing abroad), and by foreign aid. The foreign exchange required for importing oil, the price of which is exogenously specified, is first set aside from the total foreign exchange. The remaining exchange is available only for imports of raw materials, spare parts, equipment, and the like.

The GDP generated in the model is utilized for private and government (public) consumption and for investment. Government consumption



GDP	gross domestic product	CP	private consumption	⊗ summation
YA	value added in agr.	CG	govt. consumption	(-1) lag of 1 period
YNA	value added in nonagr.	KOR	incremental capital/ output ratio	

FIGURE 1 The model structure – the macroeconomic sector.

is a function of the taxes collected, which depend on the output of the agricultural and nonagricultural sectors (the income from each of these two sectors is taxed differently in India). Private consumption, on the other hand, is determined by the per capita GDP after tax, as well as by the composition of the GDP. If agricultural output increases at the same level of GDP, private consumption will increase.

The level of investment in the economy is determined by the demand for and the availability of investment. Government investment, which is determined by the amount of taxes collected and the amount of aid received, stimulates private demand for fixed investment. The level of the previous year's GDP also affects present private demand for fixed investment. Investment availability is determined by the GDP identity. The actual, or realized, investment comprises inventory formation, replacement requirement, net fixed investment in the agricultural sector, and net fixed investment in the nonagricultural sector. Net fixed investment in the nonagricultural sector, obtained as a residual, is added to the existing capital stock of the nonagricultural sector. Since there is a limited availability of arable land, an increased yield per hectare is necessary for agricultural output to be increased. To increase the per hectare yield requires an increase in the capital input to agriculture. Thus, the incremental capital/output ratio in the agricultural sector is taken to increase asymptotically with the level of agricultural output. Conversely, the incremental capital/output ratio in the nonagricultural sector, which is high at present, is expected to decline with the diversification of capital stock and the increased efficiency of capital use. The asymptotic limits of the incremental capital/output ratios are exogenously specified; their behavior is indicated schematically in Figure 2.

The Energy Sector

The structure of the energy sector is illustrated in Figure 3. The total (commercial and noncommercial) energy consumption is related to the level, structure, and characteristics of the GDP and to population. The demand for noncommercial energy is affected by per capita private consumption and by the extent of urbanization. The demand for commercial energy, obtained by subtracting noncommercial energy demand from total energy demand, is divided into electrical and nonelectrical energy. The demand for electrical energy is related to the number of villages that are supplied with electricity. Since the gas reserves of India are insignificant, nonelectrical commercial energy demand is divided into coal and oil, and oil is divided into domestic oil and imported oil. The price of imported

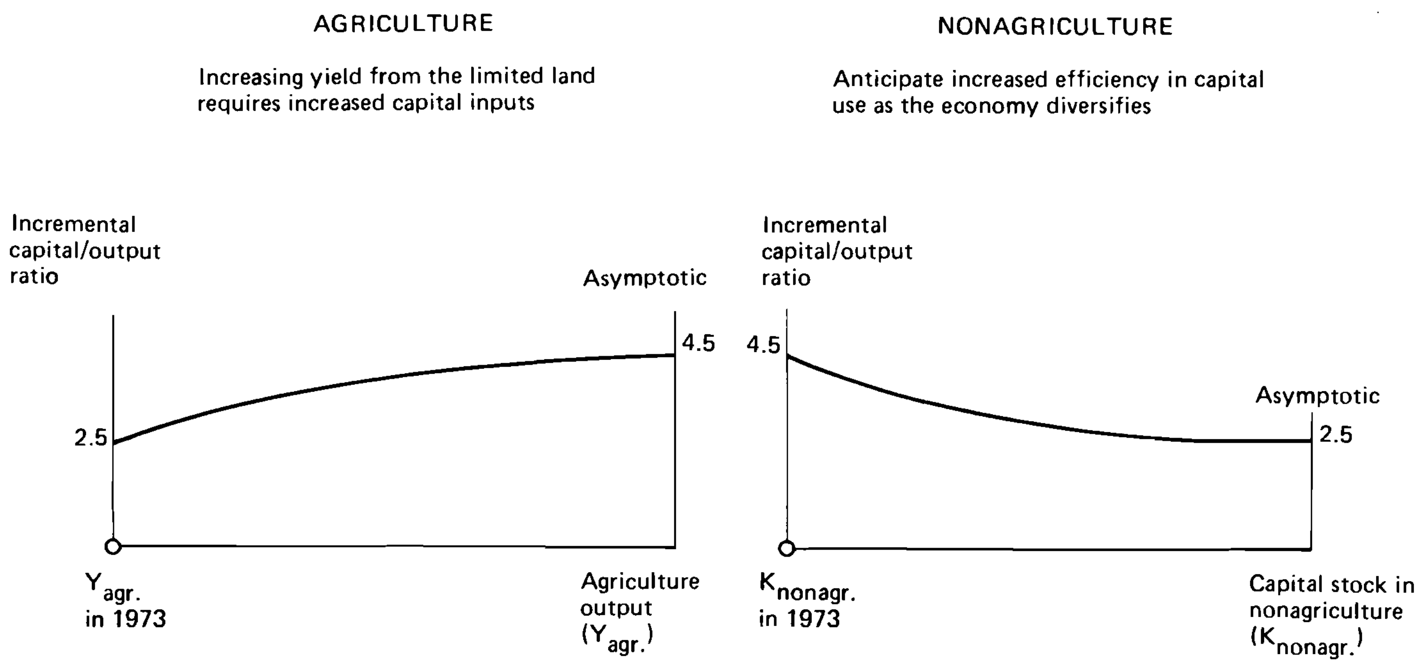


FIGURE 2 Schematic behavior of exogenously specified incremental capital/output ratios in the two sectors of the model.

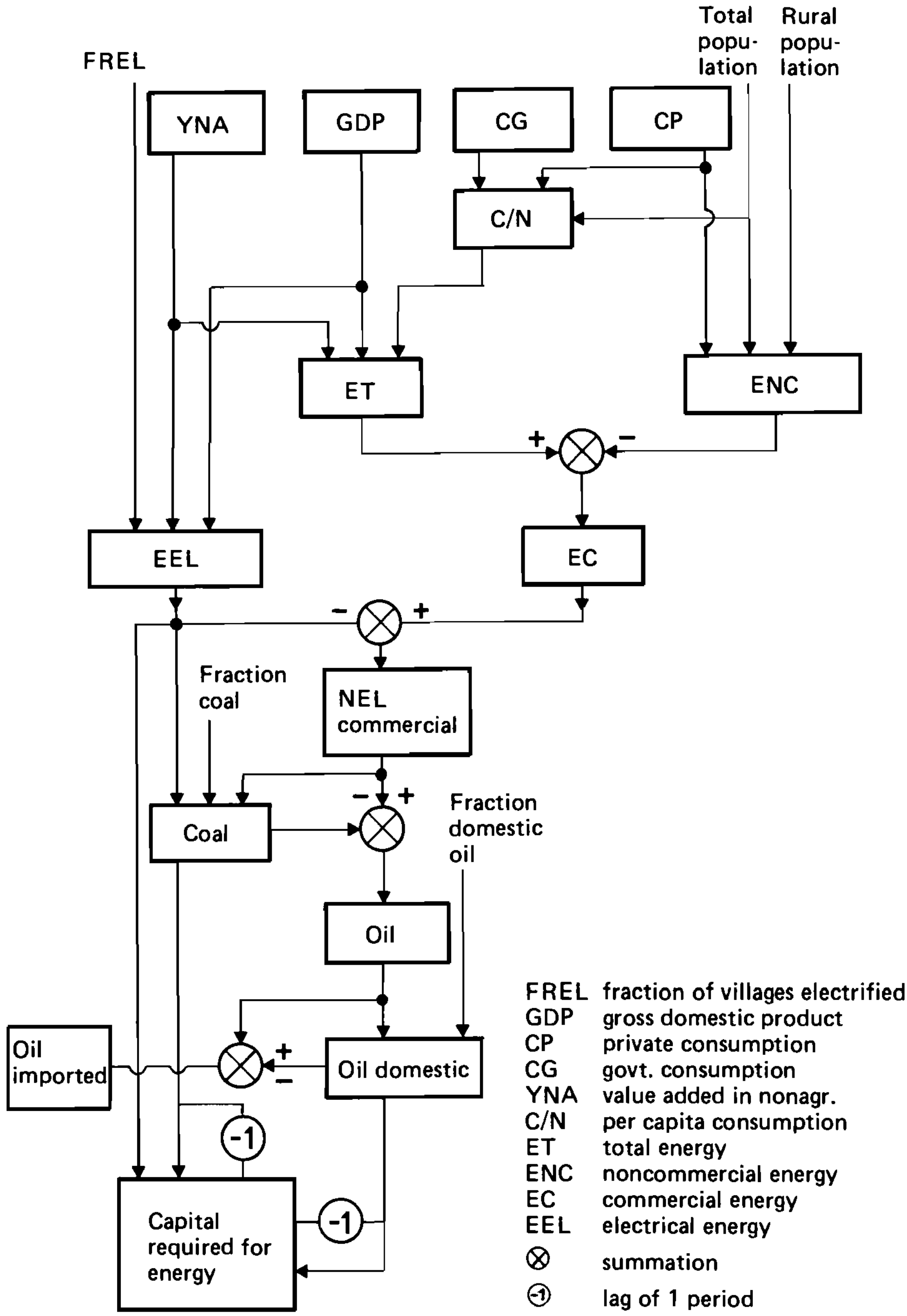


FIGURE 3 The model structure – the energy sector.

oil is specified to increase annually and to stabilize at a given level. Since the foreign exchange requirement for imported oil is subtracted from the total import availability in order to obtain imports of other raw materials, machinery, and the like, this requirement provides a feedback to the macroeconomic model, which permits investigation of the effects of oil prices on the development of the economy.

The capital required for the energy sector is then calculated using capital coefficients for the various forms of energy. Nonelectrical energy is assumed to come from coal and oil. We emphasize that this is done only to arrive at crude figures of investment requirements, ensuring the compatibility of the energy demand scenarios with the macroeconomic scenarios. The more detailed work on this aspect is being carried out within a linear programming framework using the MESSAGE model developed in the ENP at IIASA (Agnew, Schrattenholzer, Voss, 1978). In this work, a wide variety of energy conversion technologies and renewable resources are considered under various assumptions about the availability of fossil fuels. The demand results obtained from the SIMA model would be used as inputs into the MESSAGE model. If the energy supply strategy identified by the MESSAGE model is not consistent with the assumption of the particular run of the SIMA model, a new run of the SIMA model would be made with modified parameters, followed by another run of the MESSAGE model. If, in the total investment in the economy, the share of investment in the energy sector constitutes a much larger fraction of the GDP than it does at present, then it is necessary to introduce a feedback in the investment availability for the nonagricultural sector. Investment in energy above today's level can be subtracted from the investment available for nonagriculture; this will slow down the development of the economy and, in turn, the demand for energy. In the initial runs of the SIMA model, the capital stock (K) for energy is considered to be

$$K_{\text{electricity}} = K_{\text{capacity generation}} + K_{\text{transmission}} + K_{\text{rural electricity}}$$

$$K_{\text{coal}} = K_{\text{exploration}} + K_{\text{mines}} + K_{\text{railways}}$$

$$K_{\text{oil}} = K_{\text{exploration}} + K_{\text{wells}} + K_{\text{refining}}$$

Prices in the Model

The model is estimated from data at constant prices of 1970. There is no monetary sector in the model; therefore all the prices implicitly remain constant at their 1970 values. However, it is possible to change the prices of imports and exports and, in particular, the price of imported oil. All these changes are exogenously specified.

The Exogenous Variables

The important exogenous variables for the SIMA model are the growth rates of agriculture and exports, the projections of total and urban population, and the level of foreign aid. In the energy sector, the growth rate of the extension of the electricity network to rural areas, the shares of coal in electrical energy and in nonelectrical commercial energy, and the extent of self-sufficiency in oil are all specified as exogenous variables.

Readers not interested in the details of the model may skip the following section, which deals with the equations in the model.

THE EQUATIONS IN THE MODEL

The estimation of relationships is generally based on multiple regression analysis of the time series from 1950 to 1973, with some exceptions where the time series were shorter. In most cases, the data are from publications of the Government of India. The regressions were carried out by using the convenient program package developed by Norman (1978). To take account of autocorrelation, whenever it was indicated by the Durbin–Watson statistic, a first-order scheme was used, and the autocorrelation parameter space was scanned to obtain the maximum-likelihood estimate. An explanation of the symbols and units used can be found in Appendix B. In presenting the equations of the model in the text we have dropped the subscript for the current period from all variables. A subscript of -1 refers to the period preceding the current period.

The Agricultural Sector

The importance of the agricultural sector, from which, at present, almost 45 percent of the GDP originates, cannot be underestimated. Up until the mid-1960s the value added in the agricultural sector increased largely with the increase in the area under cultivation and in the irrigated area. However, over the past decade, growth in agricultural output has been principally due to the increased yields of the high-yielding crop varieties, which have ushered in the "green revolution" in agriculture in many underdeveloped countries. Growth in agricultural output in the future is much more likely to occur as a result of such technological progress and input intensification, rather than because of an extension of the area under cultivation, for which there is limited scope in India. The growth rate of the value added in the agricultural sector is prescribed exogenously:

$$YA = (1 + g)YA_{-1} , \tag{1}$$

where YA is the value added in the agricultural sector and g is the exogenously prescribed growth rate of agriculture.

However, to increase yields it is also necessary to increase investment in agriculture. The incremental capital/output ratio in agriculture increases with an increase in agricultural output, and an asymptotic function is prescribed as

$$KORA = KOA - (KOA - KIA)\frac{YA_{73}}{YA} , \tag{2}$$

where $KORA$ is the incremental capital/output ratio in agriculture, KOA is the eventual asymptotic incremental capital/output ratio in agriculture, and KIA is the initial incremental capital/output ratio in agriculture.

The Nonagricultural Sector

With increasing industrialization, the nonagricultural sector, including the energy sector, is likely to dominate the economy in the future. The value added in the nonagricultural sector depends on the productive capacity created through investment.

PRODUCTIVE CAPACITY

The incremental capital/output ratio in the nonagricultural sector in India has been high and seems to have been increasing over the last few years. This is conceivable in the preliminary stages of a developing economy in which large resources are used for building up the infrastructure, the heavy engineering capability, and the social services. The incremental capital/output ratio could be expected to decline in the future. An asymptotic function is specified to reflect this for the *capacity output of the nonagricultural sector.*

$$KOR = KO + (KI - KO)\frac{\overline{KINA}_{73}}{KINA_{-1}} , \tag{3}$$

$$YNAC = YNAC_{73} + \frac{KINA_{-1} - \overline{KINA}_{72}}{KOR}, \tag{4}$$

where KOR is the incremental capital/output ratio; KO and KI are the eventual (2030) and initial (1973) incremental capital/output ratios for the nonagricultural sector, respectively; $KINA$ is the capital stock in the nonagricultural sector; and $YNAC$ is the capacity output of the nonagricultural sector.

The incremental capital/output ratio decreases asymptotically from its initial value KI (4.5 in 1973–1974) to KO as the capital stock in nonagriculture, reflecting the diversification of the industrial base, increases (see Figure 2). In some simulation runs, KO is set to be the same as KI; therefore, the incremental capital/output ratio remains constant at the 1973 level.

Output in the nonagricultural sector will depend on the availability of imported raw materials and imported spare parts for maintenance. Thus, the *capacity utilization* may be written as

$$UC = \min\left(1.0, \frac{M245{-}9}{M2459D}\right), \tag{5}$$

where UC is the capacity utilization fraction, $M245{-}9$ is nonfuel imports of goods, and $M2459D$ is the imports required for full-capacity operations. Thus, the *value added in the nonagricultural sector YNA will be*

$$YNA = UC \cdot YNAC\,. \tag{6}$$

TOTAL GDP

The *GDP at market prices YD* is given as

$$YD = \underset{(103.7)}{1.0952}(YA + YNA) - \underset{(1.41)}{4077.2}\,, \tag{7}$$

$$R^2 = 0.999, \quad DW = 1.73, \quad 1950\text{–}1973.$$

YD is not just the sum of YA and YNA because YA and YNA are in producers' prices. In this and the subsequent equations the numbers in parentheses below the coefficients are the t values, R is the correlation coefficient, DW is the Durbin–Watson statistic, and the period, e.g., 1950–1973, refers to the period covered by the time series on which the regression is based.

CONSUMPTION

Per capita *private consumption CP* is dependent on per capita income after tax and it increases when the share of agriculture increases:

$$\underset{}{\frac{CP}{N}} = \underset{(34.2)}{0.7617}\left(\frac{YD-TX}{N}\right) + \underset{(4.14)}{48.74}\left(\frac{YA}{YNA}\right) + \underset{(1.14)}{13.59}\ , \tag{8}$$

$R^2 = 0.94,\ DW = 1.57,\ 1950–1973,$

where N is population, and TX is taxes collected.

Public consumption is a function of the taxes collected by the government CG:

$$CG = \underset{(30.8)}{0.8022}TX_{-1} + \underset{(1.51)}{1355.2}\ , \tag{9}$$

$R^2 = 0.98,\ DW = 1.53,\ 1951–1973.$

These *taxes* depend on the composition of the GDP:

$$TX = \underset{(3.41)}{0.1345}YA_{-1} + \underset{(5.08)}{0.1918}YNA_{-1} + \underset{(1.26)}{0.03}\ , \tag{10}$$

$R^2 = 0.99,\ DW = 1.75,\ 1951–1973.$

INVESTMENT

Public sector investment IG depends on foreign aid and government income from taxation.

$$IG = \underset{(5.97)}{0.4086}TX + \underset{(1.99)}{0.7886}F + \underset{(0.85)}{2641.1}\ , \tag{11}$$

$R^2 = 0.78,\ DW = 1.85,\ 1957–1972,$

where F is foreign aid in constant rupees of 1970.

The *desired gross fixed investment IFD* in the economy increases relative to the increase in the GDP and in government investment:

$$\log IFD = \underset{(10.5)}{0.7199}\log IG + \underset{(3.33)}{0.5792}\log(YD_{-1}) - \underset{(-2.31)}{3.7965}\ , \tag{12}$$

$R^2 = 0.97,\ DW = 1.30,\ 1951–1972.$

However, the *actual gross fixed investment IF* in the economy is constrained by available savings, obtained from the GDP identity

$$IF = \min\{IFD, 0.95[YD - (CP + CG + X - M)]\}, \qquad (13)$$

where X is exports of goods and services in constant rupees of 1970, and M is imports of goods and services in constant rupees of 1970, excluding net factor income payments abroad. Minimum inventory formation is assumed to form 5 percent of the actual gross fixed investment. *Actual inventory formation INV* is obtained by

$$INV = YD - (CP + CG + X - M) - IF. \qquad (14)$$

The replacement requirement for depreciated capital stock IR should depend on the gross fixed investment made in the past. Although, in principle, the replacement requirements should be made endogenous with a 20-year to 30-year lag, for computational convenience, this is not done, and the replacement requirement is taken to be 10 percent of gross fixed investment. *Net fixed investment in the nonagricultural sector INA* is obtained by subtracting the net fixed investment required for agriculture and the replacement requirement from gross fixed investment:

$$IR = 0.1IF, \qquad (15)$$

$$INA = IF - IR - KORA(YA - YA_{-1}), \qquad (16)$$

$$KINA(t) = \sum_{\tau=1950}^{t-1} INA(\tau) + INA(t). \qquad (17)$$

EXPORTS

Exports of goods depend on the volume of world trade, relative prices, and domestic production of manufactured goods. Since such a function would require an exogenous specification of the volume of world trade, we prescribe that total (goods and services) exports grow at an exogenously prescribed growth rate ϵ:

$$X = (1 + \epsilon)X_{-1}. \qquad (18)$$

IMPORTS

Imports of raw materials and spare parts depend on nonagricultural output, and imports of machinery depend on the level of investment. However, as the economy develops, this dependence on imports diminishes. Thus, *demand for such imports, required for full-capacity operations*, is obtained by

$$\frac{M2459D}{YNA} = \underset{(0.34)}{0.0306} + \underset{(3.35)}{\frac{0.0397}{\log(KINA_{-1}/100)}} - \underset{(-1.95)}{\frac{0.0472}{\log IF}} , \qquad (19)$$

$R^2 = 0.70, \; DW = 1.59.$

This makes *M2459D/YNA* asymptotic to 0.0306 over the long term. The demand for imports can be met only if foreign exchange is available. *Imports are restricted by the availability of foreign exchange* as determined by exports, private transfers, and foreign aid.

$$M = (PX \cdot X + F + TFP - YF)/PMT , \qquad (20)$$

$$M0\text{–}9 = 0.80M , \qquad (21)$$

where *TFP* is private transfers from abroad in constant rupees, *YF* is net factor income payments abroad in constant rupees, *PX* is the index of export prices, with base 1970 = 1, *PMT* is the index of import prices, with base 1970 = 1, and *M0–9* is imports of goods of Standard International Trade Classification (SITC) sectors 0 to 9. Net factor income payments abroad are a function of the foreign aid loans or private capital inflows received up to the present:

$$YF = 0.021 \cdot CTG_{-1} , \qquad (22)$$

where CTG_{-1} is the cumulative trade gap for the period preceding the current period.

Assuming no imports of food (SITC sectors 0 and 1) and normal weather, more resources are available for imports of fuel (which, for India, is oil), raw materials, and manufactured goods corresponding to SITC sectors 2, 4, and 5 to 9. Imports of fuel are made first, and the remaining exchange is used to import raw materials and manufactured goods.

$$M3 = PM_{\text{oil}} \cdot OIL^M , \qquad (23)$$

$$M245\text{–}9 = M0\text{–}9 - M3 , \qquad (24)$$

where *M3* is oil imports in 1970 rupees, OIL^M is oil imports in millions of tons, and PM_{oil} is the import price of oil in constant rupees per ton.

As the price of imported oil is varied in different scenarios relative to the price of other imports, the index of import prices *PMT* has to be adjusted. It is obtained as the weighted price of imports of oil and nonoil.

$$PMT = PM\left(\frac{M - M3}{M}\right) + \frac{PM_{\text{oil}}}{PM_{\text{oil}_0}} \cdot \frac{M3}{M} , \qquad (25)$$

where PM is the index of import prices of nonoil, with base 1970 = 1, and PM_{oil_0} is the base import price of oil in rupees of 1970, taken to be Rs 560 per ton.

Since the SIMA model is a long-term model, trade has to be balanced, although, in reality, fluctuations may continue. Thus the *trade gap* occurs only because of foreign aid. The cumulative trade gap CTG depends on the fraction of aid that is assumed to be from foreign loans FL:

$$CTG = CTG_{-1} + FL \cdot F\,. \tag{26}$$

Gross available products Y may be written as

$$Y = YD + M - X\,. \tag{27}$$

The Energy Sector

Having created a macroeconomic framework, the next step is to obtain reasonably reliable figures for the likely energy demand by relating energy consumption to the structure of the GDP. Some clarifications of the energy consumption data used in India are set out in Appendix C.

ENERGY DEMAND

The per capita energy demand ET increases with an increase in the share YNA/YD of the nonagricultural sector in the GDP and with an increase in per capita consumption C/N:

$$\log(ET/N) = \underset{(6.1)}{0.344}\log(YNA/YD) + \underset{(4.6)}{0.338}\log(C/N) - \underset{(-5.3)}{2.623}\,, \tag{28}$$

$$R^2 = 0.93,\ DW = 0.94,\ 1953\text{–}1971.$$

The share of *noncommercial energy demand ENC* in total energy declines with increasing urbanization, as measured by the fraction of the population that is urban NU/N, and with private per capita consumption CP/N:

$$\log(ENC/ET) = 2.6529 - \underset{(-4.0)}{0.5239}\ \log(NU/N) - \underset{(-4.78)}{0.6212}\ \log(CP/N)\,, \tag{29}$$

$$R^2 = 0.97,\ DW = 1.68,\ 1953\text{–}1971.$$

The share of *commercial energy demand EC* can then be obtained as a residual:

$$EC = ET - ENC. \tag{30}$$

The growth rate of electrical energy supply in the developing countries is usually higher than in the developed world because there is usually a large backlog of demand for electricity in rural areas. In 1972, one-quarter of all villages in India were receiving electricity. The pace at which full electrification will be reached is represented in the SIMA model as a scenario variable. The share of electrical energy in the commercial energy sector rises with the number of villages supplied with electricity as a percentage of the total number of villages *FREL* and with the activities in the non-agricultural sector. *Electrical energy demand EEL* may be written as

$$\begin{aligned} \log(EEL/EC) &= \underset{(-12.2)}{-3.78} + \underset{(10.4)}{0.2985} \log(FREL) + \underset{(1.91)}{0.2378} \log(YNA/YD)\,, \\ R^2 &= 0.98,\quad DW = 1.81,\quad 1953\text{–}1971. \end{aligned} \tag{31}$$

Nonelectrical energy demand NEL, therefore, is

$$NEL = EC - EEL. \tag{32}$$

CAPITAL REQUIRED FOR THE ENERGY SECTOR

India has abundant coal, small gas reserves, and moderate oil resources. For the present, we do not include the recurring maintenance and operating cost requirements for the energy sector, but consider only the capital requirements for additional facilities.

Taking the different load factors into consideration, we assume that, in the long run, the capital costs per kilowatt (kW) of capacity will be approximately Rs 3,000 for coal, hydroelectric power (which, in the future, would have a very low load factor), or nuclear power (with a higher load factor than coal), even though hydroelectric power and coal are cheaper at present. These costs include transmission and distribution costs. However, for supplying rural areas with electricity, special efforts to set up subtransmission lines have to be made; they require additional investment. Thus total *capital for electricity production* is obtained as

$$DFREL = FREL - FREL_{-1}\,, \tag{33}$$

$$DEKW = (EEL - EEL_{-1})1.42\,, \tag{34}$$

$$KEL = 3{,}000DEKW + 82{,}500DFREL\,, \tag{35}$$

where *DFREL* is the additional number of villages supplied with electricity as a percentage of the total number of villages; *DEKW* is the additional electrical capacity required, in millions of kilowatts, assuming a utilization factor of 4,000 kWh/kW; and *KEL* is the capital investment required for electricity, in millions of constant rupees.

The amount of coal required, in millions of tons, is

$$COAL = NEL \cdot F_{\text{coal}} , \qquad (36)$$

where F_{coal} is the fraction of nonelectrical energy coming from coal. Thus the additional annual coal requirement, that is, coal used for more than nonelectrical energy production, would be

$$DCOAL = COAL - COAL_{-1} + \frac{1}{1.42} DEKW\, F_{\text{el}}^{\text{cl}} , \qquad (37)$$

where *DCOAL* is the additional annual coal requirement, in millions of tons, and $F_{\text{el}}^{\text{cl}}$ is the fraction of electricity generated from coal-based plants.

At present the capital requirement for mining and transporting one ton of additional coal is Rs 210. However, as mines become deeper and railroads get congested, the capital requirements will continue to increase. The *annual capital needed to increase coal capacity by the additional annual coal requirement* is

$$KCOAL = K_{\text{coal}}^{\text{mine}} + K_{\text{coal}}^{\text{transp.}} , \qquad (38)$$

$$KCOAL = 210(1 + \rho_{\text{coal}})^t DCOAL , \qquad (39)$$

where ρ_{coal} is the exogenously specified growth rate of the capital cost of mining and transporting coal.

Since the amount of electricity generated by oil-based plants is negligible at present, oil requirements are assumed to be for nonelectrical uses only. The amount of oil required *OIL*, in millions of tons, is

$$OIL = 2(NEL - COAL) . \qquad (40)$$

Of this, OIL^{D} will be domestic oil. The availability of domestic oil is exogenously assumed to stabilize at various levels for different scenarios. The capital required $K_{\text{oil}}^{\text{D}}$ for exploration and drilling to increase domestic oil production, is

$$K_{\text{oil}}^{\text{D}} = 3{,}000(OIL^{\text{D}} - OIL_{-1}^{\text{D}}) . \qquad (41)$$

This could also be obtained through coal liquefaction, in which case the capital requirements per ton of production capacity are assumed to be the same – Rs 3,000 per ton. The additional annual oil requirement *DOIL*, in millions of tons, is

$$DOIL = (OIL - OIL_{-1}) . \qquad (42)$$

Even though some crude oil is imported, it is assumed that all oil will continue to be refined in India. The capital required to increase the refinery capacity $K_{\text{oil}}^{\text{R}}$ is

$$K_{\text{oil}}^{\text{R}} = 120 \cdot DOIL . \qquad (43)$$

Thus, total *capital required for oil production KOIL* is

$$KOIL = K_{\text{oil}}^{\text{D}} + K_{\text{oil}}^{\text{R}} . \qquad (44)$$

Thus one may add up the various capital requirements to obtain the *total annual capital for the energy sector KEN*, in millions of rupees:

$$KEN = KEL + KCOAL + KOIL . \qquad (45)$$

This capital requirement is only for net investment. Investment for the replacement of depreciated capital stock in the energy sector is included in the aggregate replacement requirements. With the exception of coal, for which a 1.5 percent increase in capital cost per year is assumed, the capital costs of other energy supplies are kept constant. The oil industry has been developed relatively recently in India, and future increases in costs because of resource depletion should be compensated for by the benefits of experience. The electrical power plant industry is well established, and one may not expect any change in costs. If the future energy supply is to be based on a much more expensive energy source, the demand projection would need to be revised.

In addition to the capital costs in the energy sector, one should also consider operating and import costs in order to account for the total cost of energy. Costs of oil imports can be determined from the import price of oil, which is exogenously given. A gradual increase in the price of imported oil is assumed. If oil prices were to rise suddenly, then the energy demand estimated might need to be revised. The nonfuel operating costs of coal mines, power plants, oil refineries, and transport and transmission networks have to be added to operating and import costs.

3 GENERATION OF SCENARIOS AND NUMERICAL RESULTS

THE SCENARIO SPECIFICATION

Different scenarios can be generated by specifying alternative sets of values for the exogenous variables and by altering some of the relationships involving certain endogenous variables. For example, the tax equation can be modified to reflect increased government effort at development. Similarly, the incremental capital/output ratio can be changed to reflect increased capital costs of energy, if such a supply scenario is envisaged.

Although a large number of scenarios could be generated with the model, we restrict ourselves to a few that are of policy interest, evaluating these against a "base case." The simulation carried out covers the period from 1974 to 2030, and the results of these runs are presented in this section. The base case will be described in detail, whereas only the important results of the other scenarios are given. The scenarios are constructed so that each one represents an additional policy measure, and, therefore, the growth of the economy improves with each additional step, the base case being the lowest of all.

THE BASE CASE

The Scenario Specification of the Base Case

The base case is considered to be a "business as usual" scenario in which no drastic policy changes or shifts in the availability of resources take place. The exogenous parameters and their specifications for the base case, and for the other scenarios, together with some initial conditions, are given in Tables 1 and 2. Some observations on these specifications follow.

To specify total population as well as its urban/rural makeup, the medium variant projections of the United Nations (1975) for population and urbanization are taken as reference points for the year 2000. An asymptotic equation is obtained by assuming that eventually the population stabilizes at 1,500 x 10^6.

$$N = 1{,}500/(1 + 1.5e^{-0.375t}) \, , \quad t = 1 \text{ in } 1974 \, . \tag{46}$$

This gives a population estimate for the years 2000 and 2030 of 958 x 10^6 and 1,267 x 10^6, respectively. The growth rate of urbanization estimated from the medium variant figure given by the United Nations (1975) for 2000 is 1.627 percent. This gives an estimate of urban population as 32 per-

TABLE 1 Exogenous parameters and variables and their specifications.

Symbol	Exogenous parameters and variables	Value
N	Population (x 10^6)[a]	
NU	Urban population (x 10^6)[a]	
IR	Investment for replacement of depreciated capital stock (Rs x 10^6)[a]	
KI	Initial incremental capital/output ratio for the nonagricultural sector	4.5
KO	Long-term incremental capital/output ratio for the nonagricultural sector[b]	
KOA	Long-term incremental capital/output ratio for the agricultural sector[b]	
KIA	Initial incremental capital/output ratio in agriculture	2.5
ρ_{coal}	Growth rate of capital costs of coal (%)	1.5
ρ_{oil}	Growth rate of import price of oil (%)	2.0
ER	Exchange rate (Rs/$ of 1970)	7.5
PX	Index of exports prices (base 1970 = 1)	1.4
PM	Index of nonoil imports prices (base 1970 = 1)	1.5
F	Foreign aid (constant Rs x 10^6 of 1970)[a]	
FL	Fraction of foreign aid given as loans	0.5
TFP	Private transfers from abroad (constant Rs x 10^6)[a]	
$FREL$	Number of villages supplied with electricity as a percentage of total number of villages[a]	
F_{coal}	Fraction of nonelectrical energy from coal[a]	
OIL^D	Domestic oil production (10^6 tons)[b]	
F_{el}^{cl}	Fraction of electricity generated from coal-based plants	0.5

[a]Values depend on time but do not change with scenarios and are given in Table 4.
[b]Exogenous variables that change for each scenario; values given in Table 3.

TABLE 2 Exogenous variables for different scenarios.

Scenarios	Percentage annual growth rate Base case 1	Lower KOR^a 2	Increasing aid 3	High growth due to high tax[b] 4
Export	5.0	5.0	5.0	7.0
Agr. output	3.0	3.0	4.0	4.0
Foreign aid	0	0	3.0	3.0
Asymptotic KOR^a for nonagr.	4.5	2.5	2.5	2.5
Stabilization level of domestic oil production (10^6 tons)[c]	45.0	45.0	65.0	90.0

[a] *KOR* is incremental capital/output ratio.
[b] The tax rate (*Tx*) is increased by 50 percent without affecting public government consumption (*CG*) by tax and public consumption equations

$$Tx = 1.5(0.2117YA_{-1} + 0.2395YNA_{-1} - 277.4)$$

$$CG = 0.8033(0.667)Tx_{-1} + 1308 \, .$$

[c] The actual growth over time is given for each scenario in summary tables.

cent and 52 percent of total population by 2000 and 2030, respectively, assuming the same growth rate after 2000.

An asymptotic equation for the supply of electrification to rural areas is obtained by assuming that, starting from a base level of 25 percent in 1972, by 2000 90 percent of rural areas receive electricity, and by 2025 all rural areas have electricity.

$$FREL = 100/(1 + 2.81e^{-0.124t}) \, , \quad t = 1 \text{ in } 1974 \, . \tag{47}$$

It was assumed in all scenarios that two-thirds of nonelectrical energy is obtained from coal by 1980 and that the capital cost for coal increases by 1.5 percent annually.

The import price of oil also increases by 2.0 percent annually. This means that the price of oil in rupees of 1970 is Rs 560 per ton in 1974, increasing to Rs 1,200 by 2016, and stabilizing thereafter. The definition of the base case and variations over the base case are illustrated in Figure 4.

The Numerical Results of the Base Case

Numerical results for every 5 years are given in Table 3, and several important variables are plotted in Figures 5 and 6. The per capita GDP increases

DEFINITION OF THE BASE CASE

"DRIFT" SCENARIO DETERMINED BY PAST INPUTS

- Growth in agricultural output 3% (1950–1973 growth rate = 2.3%)
- Foreign aid constant at \$1,000 x 10^6 /year (current rate)
- Marginal capital/output ratio in nonagriculture remains constant at a value of 4.5

INPUTS COMMON TO ALL SCENARIOS

	1971	2000	2025
• Total population (x 10^6)	570	960	1,230
• Urban population (% of total)	20	32	48
• Villages electr. (% of total)	25	90	99

	% Growth rates
• Exports	5.0
• Price of oil	2.0
• Capital cost for coal	1.5

VARIATIONS OVER BASE CASE

A "Low incremental capital/output ratio"

- Incremental capital/output ratio in nonagriculture decreases to a value of 2.5
- Otherwise like base case

B "High agr. growth, increased foreign aid"

- Agricultural growth rate increases to 4% (from 3%)
- Foreign aid growth rate increases to 3%
- Otherwise like A

C "High growth"

- Tax rate increases by 50%
- Export growth rate increases to 7% (from 5%)
- Otherwise like B

FIGURE 4 Definition of the base case of the SIMA model and scenario generation (through exogenous specifications).

from Rs 687 in 1970, to Rs 1,478 in 2000, and to Rs 3,628 in 2030. The GDP growth rate of 2.5 percent is modest but is an improvement on the growth rate of less than 1.5 percent over the past three decades. The overall GDP growth rate is 4.3 percent. This is slightly better than the economy's past performance in the base case, which has been described above as business as usual, without major policy changes, and is not unreasonable. Until recently, the population growth rate had been decelerating at a faster rate than expected. Moreover, the performance of the export sector has also improved significantly in the recent past. Per capita annual consumption of total (commercial and noncommercial) energy increases from 0.49 tons of coal equivalent (tce) in 1970, to 0.68 tce in 2000, and to 0.94 tce in 2030. The per capita consumption of commercial energy, however, increases at a faster rate than the per capita consumption of total energy, increasing from 0.165 tce per capita in 1970, to 0.43 tce in 2000, and 0.79 tce in 2030. Since commercial energy is usually used more efficiently than noncommercial energy, the total usefully consumed energy increases at a faster rate than that shown by the primary energy consumption in coal equivalent units. Moreover, the commercial energy consumption considered here excludes conversion losses and therefore appears smaller than the actual energy production required, as can be seen by adding together the net primary energy of coal, oil, and electrical energy produced from coal.

Electrical energy demand grows from 67×10^9 kilowatt hours in 1975 to 376×10^9 kWh in 2000 (including distribution losses), that is, an annual growth rate of 7 percent. However, its long-term growth rate is small (4.9 percent), because of the low growth rate of the GDP. The capacity requirements are 92 gigawatts (GWe) in 2000 and 230 GWe in 2030.

The capital requirements in the energy sector are especially high in the initial years because of oil exploration activities and the extension of the electricity supply to rural areas, requiring 10–18 percent of government investment; in later years, import requirements rise. During the period 1980–1990, the imported oil requirements decline because of increases in domestic oil production, and only 8–11 percent of export earnings is required for importing oil. Domestic oil production stabilizes at 45×10^6 tons per year in 2005. In 2030, 42 percent of total export earnings is required to import almost 100×10^6 tons.

The coal requirements, including the requirements for power generation, are 345×10^6 tons in 2000, increasing to 845×10^6 tons in 2030.

ALTERNATIVE SCENARIOS

In addition to the base case, three alternative scenarios were run. The parameters, which were varied in these scenarios, are summarized in Table 2,

TABLE 3 The base case results.[a]

	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	1,RATE	2,RATE
YA/YO	0.42	0.38	0.35	0.33	0.31	0.28	0.26	0.25	0.26	0.24	0.23	0.21	-1.55	-1.23
YO	457.68	587.82	725.50	900.31	1127.32	1416.10	1776.71	2133.58	2438.00	2957.93	3656.98	4595.51	4.62	4.28
YA	192.83	221.22	256.45	297.30	344.65	399.55	463.18	536.96	622.48	721.63	836.56	969.81	3.00	3.00
YNA	231.15	319.22	409.19	527.55	686.47	897.27	1162.97	1414.50	1607.91	1980.94	2506.01	3230.38	5.57	4.91
C	381.25	479.39	585.16	718.78	890.21	1109.67	1383.84	1657.47	1890.42	2288.50	2820.16	3538.75	4.37	4.13
CP	327.94	408.25	497.03	609.01	752.88	935.94	1164.51	1389.19	1583.20	1920.53	2362.75	2960.05	4.28	4.08
CG	53.43	71.14	87.94	109.41	137.43	173.84	219.46	268.05	307.47	367.50	456.36	575.45	4.83	4.42
TX	64.91	86.99	107.93	134.70	164.63	215.02	271.88	332.45	381.60	456.42	567.19	715.66	4.91	4.46
IG	33.39	42.41	50.97	61.90	76.18	94.72	117.96	142.71	162.79	193.36	238.62	299.28	4.26	4.07
I	83.29	116.45	147.91	187.79	239.89	305.17	377.50	438.75	478.81	580.34	720.93	914.08	5.33	4.45
IF	74.03	103.17	132.97	173.20	227.87	289.90	358.59	417.15	454.48	552.07	685.16	871.09	5.61	4.56
IAG	14.65	18.75	23.51	29.02	35.41	42.82	51.41	61.37	72.92	86.30	101.82	119.81	4.39	3.90
INA	51.98	74.10	96.17	126.86	169.62	218.04	271.30	314.22	335.99	410.43	516.53	667.28	5.90	4.75
INV	9.14	13.28	15.12	14.92	12.00	15.29	18.90	21.67	24.19	28.85	34.64	42.05	2.08	2.81
IR	7.40	10.32	13.30	17.32	22.78	28.99	35.86	41.73	45.44	55.21	68.61	87.30	5.61	4.59
X	19.71	25.15	32.10	40.97	52.29	66.73	85.17	108.70	138.73	177.06	225.98	288.41	5.00	5.00
PX	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	00.00	00.00
PH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	00.00	00.00
F	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	00.00	00.00
TFP	2.00	3.60	3.97	4.39	4.85	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.73	1.68
YF	0.06	0.34	0.62	0.90	1.18	1.46	1.74	2.02	2.31	2.59	2.87	3.15	13.92	7.59
H	26.87	33.17	39.22	46.43	55.15	65.57	69.95	70.92	70.51	86.60	110.05	142.97	3.63	3.09
PHOIL	571.20	630.65	696.29	768.76	848.77	937.11	1034.65	1142.34	1260.00	1260.00	1260.00	1260.00	2.00	1.45
MOIL	7.07	4.74	6.53	9.09	11.96	14.96	28.15	44.39	60.97	78.56	98.93	122.21	3.04	5.32
M245-9	14.63	19.07	20.68	23.35	27.22	31.42	35.82	35.02	29.26	34.37	44.26	60.08	3.11	2.60
YOPC	745.47	861.26	964.52	1095.24	1264.35	1478.08	1739.88	1975.86	2148.84	2500.14	2978.10	3628.58	2.78	2.92
CPPC	534.30	598.16	660.64	740.67	844.35	976.87	1140.36	1286.48	1395.50	1622.94	1925.02	2338.40	2.44	2.72
CGPC	87.08	104.23	116.84	132.99	154.15	181.47	214.93	248.19	271.06	310.48	371.65	454.10	2.98	3.05
ETPC	0.50	0.54	0.57	0.60	0.63	0.67	0.72	0.75	0.77	0.82	0.87	0.94	1.16	1.14
ECPC	0.18	0.23	0.27	0.32	0.37	0.43	0.50	0.54	0.58	0.64	0.71	0.79	3.55	2.71
ENCPC	0.32	0.31	0.29	0.27	0.26	0.24	0.22	0.21	0.19	0.18	0.17	0.15	-1.18	-1.37
EELPC	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.09	0.10	0.12	0.13	5.20	3.56
ET	309.42	367.97	425.58	490.38	563.65	644.95	733.06	812.30	875.56	966.02	1070.69	1190.61	2.98	2.48
EC	111.20	157.32	206.07	264.58	334.19	415.05	505.52	588.10	655.25	754.00	868.12	999.42	5.41	4.07
ENC	198.14	210.60	219.61	225.96	229.43	229.86	227.50	224.24	220.26	212.14	202.70	191.50	0.60	-0.06
EEL	11.67	18.95	27.47	37.96	50.38	64.70	80.56	94.78	105.92	122.67	142.20	164.81	7.09	4.93
NEL	99.48	138.37	178.66	226.72	283.77	350.30	424.92	493.34	549.31	631.38	726.11	834.91	5.16	3.94
OIL	20.39	23.52	30.38	38.55	48.23	59.54	72.23	83.87	93.38	107.34	123.47	141.97	4.38	3.59
OILD	6.00	16.00	21.00	26.74	34.13	43.56	45.00	45.00	45.00	45.00	45.00	45.00	7.01	3.19
OILM	12.38	7.52	9.38	11.82	14.09	15.98	27.22	38.87	48.39	62.34	78.50	96.99	1.02	3.81
KOR	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	00.00	00.00
KORA	2.56	2.83	3.06	3.25	3.42	3.57	3.70	3.81	3.90	3.99	4.06	4.12	1.34	0.87
N	613.55	682.51	752.64	822.72	891.55	957.98	1021.06	1080.02	1134.32	1183.66	1227.93	1267.23	1.80	1.33
NU	132.39	159.65	190.85	226.15	265.66	309.45	357.55	409.97	466.77	528.01	593.79	664.30	3.45	2.98
NR	481.16	522.86	561.79	596.57	625.88	648.53	663.52	670.05	667.55	655.65	634.14	602.93	1.20	0.41
FREL	287.17	428.20	581.96	721.28	827.90	899.42	943.26	968.65	982.89	990.72	994.99	997.30	4.67	2.29

[a]See Appendix B for an explanation of the symbols.

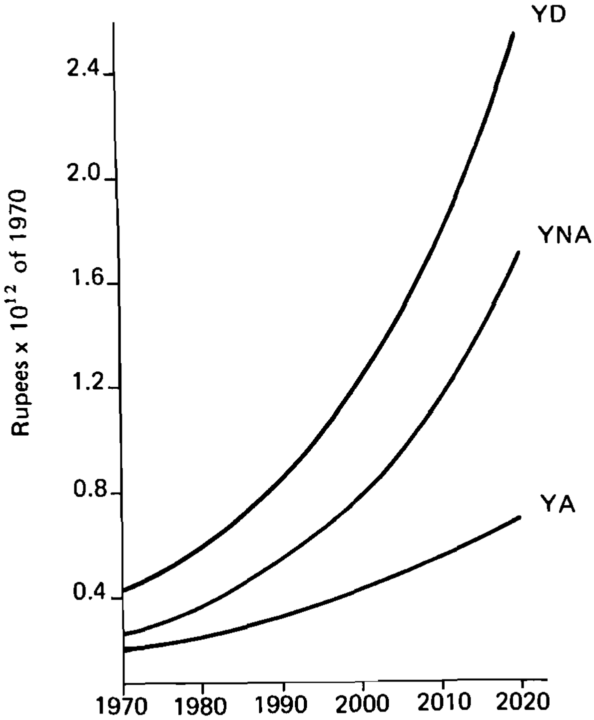


FIGURE 5 The GDP and sectoral outputs for the base case in rupees x 10^{12} of 1970.

and the important details of the results for these scenarios for selected years are given in Appendix D. To emphasize the effects of the changes in assumptions, the important results are summarized for the years 2000 and 2030 in Table 4.

In discussing the results, we refer mostly to the values for 2000, because in 2030 the same phenomena are only extended further in time; this can be seen in the comparative table provided in Appendix D.

The "Lower Incremental Capital/Output Ratio" Scenario

The incremental capital/output ratio in nonagriculture, which has been increasing over the past two decades and has been assumed to remain at a value of 4.5 (its recent value) in the base case, is assumed to decrease asymptotically to 2.5 (see Figure 2). Thus, this scenario will indicate the effects of a more efficient use of capital, which can be expected through diversification of capital stock, through the formation of a skilled labor force, or through the introduction of appropriate policies. The annual

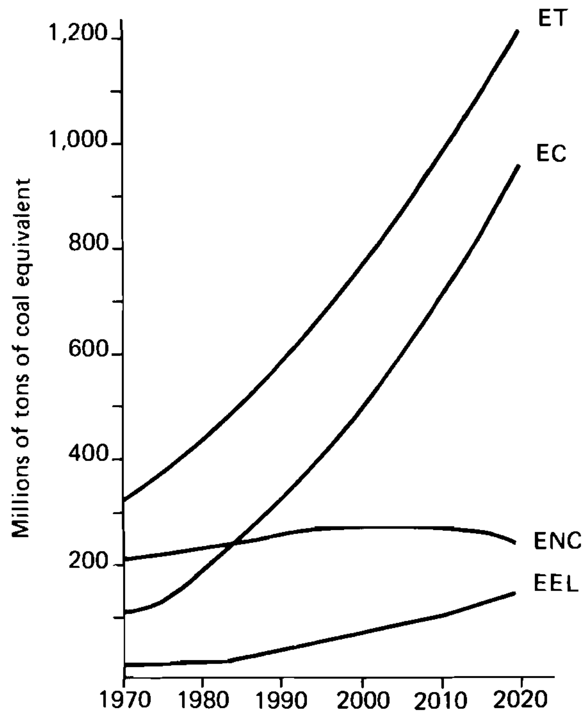


FIGURE 6 Consumption of energy for the base case in millions of tons of coal equivalent.

growth rate of the GDP is 5.46 percent between 1975 and 2000 and 4.55 percent between 1975 and 2030. The output of the nonagricultural sector grows at 6.74 percent and 5.25 percent for the same periods, respectively.

In this lower incremental capital/output scenario, energy requirements increase from 89 x 10^6 tce in 1970 to 482 x 10^6 tce in 2000 for commercial energy, from 174 x 10^6 tce to 224 x 10^6 tce for noncommercial energy, and from 263 x 10^6 tce to 706 x 10^6 tce for total energy. In 2030, the requirements are 1,075 x 10^6 tce for commercial, 187 x 10^6 tce for noncommercial, and 1,262 x 10^6 tce for total energy. Electrical energy generation increases from 55 x 10^9 kWh in 1970, to 446 x 10^9 kWh in 2000, and to 1,040 x 10^9 kWh in 2030. Electrical energy as a percentage of commercial energy is 8.99 percent for 1970, 15.89 percent for 2000, and 16.64 percent for 2030.

The net fixed investment requirements for producing, transforming, transporting, and transmitting fuels and energy account for 9.4 percent of the total net fixed investment in the economy in 2000 and 4.1 percent

TABLE 4 Summary results of different scenarios.

Variable symbols[a]	1970	2000 Base case 1	2000 1 + low KOR^a 2	2000 2 + high agr. + aid 3	2000 3 + high growth 4	2030 Base case 1	2030 1 + low KOR^a 2	2030 2 + incr. agr. + aid 3	2030 3 + high growth 4
YD (Rs x 10^9)[b]	398	1,416	1,727	1,809	2,620	4,595	5,277	6,932	22,442
YA/YD	0.48	0.28	0.23	0.29	0.20	0.21	0.18	0.24	0.07
$YDPC$ (Rs)[b]	687	1,478	1,804	1,887	2,732	3,628	4,168	5,469	17,712
ET (10^6 tce)[c]	263	645	706	697	801	1,190	1,262	1,344	2,097
ENC (10^6 tce)[c]	174	229	224	214	209	191	187	168	135
EC (10^6 tce)[c]	89	415	482	483	592	999	1,076	1,176	1,962
EEL (10^9 kWh)[c]	55	378	448	436	553	960	1,041	1,117	1,960
$ETPC$ (tce)[c]	0.49	0.67	0.74	0.73	0.84	0.94	1.00	1.06	1.65
$ECPC$ (tce)[c]	0.16	0.43	0.50	0.50	0.62	0.79	0.85	0.93	1.55

[a] The variable symbols are as follows: *KOR* – incremental capital/output ratio; *YD* – GDP at market prices; *YA* – value added in the agricultural sector; *YDPC* – per capita GDP at market prices; *ET* – energy demand; *ENC* – noncommercial energy; *EC* – useful energy, excluding conversion losses, energy required in the energy sector, and transmission losses (to convert into primary energy, useful energy should be multiplied by a factor of one-quarter); *EEL* – electrical energy at a consumer point; *ETPC* – per capita energy demand; *ECPC* – per capita useful energy.

[b] $1 is the equivalent of Rs 7.5.

[c] Coal in India has 5,000 kcal/kg, 1 x 10^6 tce of Indian coal is equal to 0.7125 x 10^6 tce of UN coal.

in 2030. However, these requirements account for approximately 30 percent of net government investment in 2000 and 12 percent in 2030. The three reasons for this decline are as follows: in 2030, investment in rural electrification is no longer required; oil imports increase (to generate export earnings for the purchase of oil, investment in other sectors, not considered here, would be required); and exports also increase.

The per capita GDP in 2000 rises from Rs 680 in 1970 to Rs 1,615, compared with Rs 1,339 in the base case. Total per capita energy consumption increases to 0.755 tce in 2000, compared with the base-case consumption of 0.08 tce.

The "Low Incremental Capital/Output Ratio, High Agricultural Growth, Increasing Foreign Aid" Scenario

Foreign aid increases at 3 percent annually in this case as compared to other cases, where it is kept constant at the level of Rs 5.5 billion a year, reaching a level of Rs 28 billion in 2030. From 1975 to 2030, the GDP and energy consumption grow at 5 percent and 4.36 percent, respectively.

The per capita GDP and per capita energy consumption rise to Rs 1,887 and to 0.50 tce, respectively, in 2000. Although this means that the capital requirements for energy increase, the economy is able to provide for these with the same percentage of fixed investment, since the level of fixed investment is also higher than in the base case. It should be noted that the high economic growth achieved through more rapid agricultural development and increasing foreign aid does not require a similar rise in the growth rate of energy consumption.

The "High Economic Growth" Scenario

The tax rate is increased by 50 percent, but the level of government consumption is not allowed to increase as a result of this, so the additional tax is available for public investment. The growth rate of exports is also increased to 7 percent, compared with 5 percent in the other scenarios. These changes are in addition to high agricultural growth, a low incremental capital/output ratio, and increasing foreign aid. This scenario projects a high economic growth rate and shows its effect on energy consumption. Although all the optimistic assumptions of this scenario may be considered unlikely to come about, the scenario is useful for defining some extreme values.

The high economic growth rate leads to 5.90 percent growth in the per capita GDP (Rs 2,732 by 2000, and Rs 17,712 by 2030) and 2.22

percent growth in the total per capita energy consumption reaching a level in 2030 of 1.65 tce per capita, of which commercial energy accounts for 1.55 tce. Although in the initial stage the increased tax rate restricts private consumption, the economy develops rapidly as these taxes are diverted to fixed investment; in less than 5 years this increases private consumption, as compared with private consumption in the base case.

4 CONCLUSIONS

During the period 1953–1971, when the price of energy was not high and India was at a preliminary stage of industrial development, the growth rate of commercial energy consumption was 5.3 percent, compared with the economic growth rate of 3.8 percent. In the base case, over the period 1975–2000, in which the commercial energy consumption growth rate is 5.4 percent, the economic growth rate is 4.6 percent. In the base case, for the period 1975–2030, the growth rate of commercial energy consumption is 4.0 percent, and the growth rate of the economy is 4.3 percent. However, over the short term, for example, 1975–1985, the growth rate of commercial energy consumption is higher at 6.3 percent, whereas the economic growth rate is 4.7 percent. In the high growth scenario, in which the economic growth rate is 7 percent, the growth rate of commercial energy consumption is relatively low (5.6 percent). Thus, the growth rate of commercial energy consumption increases with the growth rate of the economy, but at a slower rate. Moreover, the growth rate of commercial energy consumption falls with time, since the substitution of commercial energy for noncommercial energy is higher in the early years.

The energy demand generated from the scenarios with modest economic growth does not appear to pose any special problems of capital requirements for the energy sector. However, our estimates of the net capital requirement for the energy sector are fairly crude. A detailed supply analysis that uses these demand projections is under way. By optimizing the net capital investment for energy, the capital for replacement, and operating and maintenance costs, the analysis arrives at an optimal energy supply mix. It considers a wide variety of new energy conversion technologies, in order to obtain further insight into the capital requirements of the energy sector (J. Parikh and M. Agnew, Energy Supply Choices for India, in preparation).

From the numerical results of the four scenarios examined we can draw some conclusions:

(a) In 2000 (2030) the total energy consumption in India ranges from 645×10^6 tce ($1,190 \times 10^6$ tce) to 801×10^6 tce ($2,097 \times 10^6$ tce). Consumption of commercial energy, however, ranges from 415×10^6 tce (999×10^6 tce) to 592×10^6 tce ($1,962 \times 10^6$ tce), growing at 5.4 percent and 7.3 percent until 2000 for the base case and high growth scenarios, respectively. Noncommercial energy consumption grows at 0.8 percent and 0.5 percent for the base case and high growth scenario, respectively, and has a zero or negative growth rate during the period 2000–2030 for all cases with the exception of the base case. As mentioned before, the high growth scenario is developed only to obtain upper limits and seems at present to be highly optimistic, even though it is feasible.

(b) The consumption of electrical energy in 2000 (2030) is projected to be between 378×10^9 kWh (960×10^9 kWh) and 553×10^9 kWh ($1,960 \times 10^9$ kWh). Electrical energy is 15–17 percent of commercial energy consumption in 2030.

(c) The demand for noncommercial energy ranges between 135×10^6 tce and 191×10^6 tce, but as a percentage of total energy consumption, it declines to 15 percent or less in 2030. Such a level of noncommercial energy consumption for a period as long as 50 years may be considered ecologically undesirable. However, whatever substitutes are provided for noncommercial fuels, they must be institutionally acceptable and economically feasible.

(d) Comparisons between scenarios (b) and (c) show that macroeconomic growth, if achieved by an intensification of the nonagricultural sector, implies a substantial growth in the energy requirements. Economic growth achieved by an intensification of the agricultural sector does not have such a high energy requirement. However, this alone cannot be taken as a decisive factor in the consideration of alternative policies for macroeconomic growth. Foreign aid, at the level we have assumed (3 percent growth), has little impact on energy demand and the whole economy.

In addition to providing energy demand estimates up to the year 2030, the SIMA model provides insights into the growth rate of energy demand and its relation to macroeconomic variables.

APPENDIXES

Appendix A

COAL REPLACEMENT AND EQUIVALENT UNITS OF DIFFERENT FUELS

Fuel	Unit	Coal equivalent in tons (tce)	Coal replacement in tons (tcr)
Coal (coking 6,640 kcal/kg; noncoking coal used in steam generation 5,000 kcal/kg)	1 ton	1.0	1.0
Hard coke	1 ton	1.3	1.3
Soft coke	1 ton	1.5	1.5
Firewood and agricultural waste (4,750 kcal/kg)	1 ton	0.95	0.95
Charcoal (6,900 kcal/kg)	1 ton	1.0	1.0
Animal dung (3,300 kcal/kg dry)	1 ton	0.66	0.4
Oil products (10,000 kcal/kg)			
Kerosene and liquefied petroleum gas	1 ton	2.0	8.3
Diesel oil	1 ton	2.0	9.0
Motor spirit and jet fuel	1 ton	2.0	7.5
Natural gas (9,000 kcal/kg)	$10^3 m^2$	1.8	3.6
Electricity	10^3 kWh	0.172 electric or 0.6 thermal	1.0

Appendix B

THE SYMBOLS AND UNITS OF MEASUREMENT USED IN TABLE 3 AND TABLES D.1 TO D.3[a]

Symbol	Variable	Unit
YD	Gross domestic product (GDP)	Rs x 10^9 of 1970
YA	GDP from agricultural sector	Rs x 10^9 of 1970
YNA	GDP from nonagricultural sector	Rs x 10^9 of 1970
YNAC	Capacity output	Rs x 10^9 of 1970
C	Consumption	Rs x 10^9 of 1970
CP	Private consumption	Rs x 10^9 of 1970
CG	Government consumption	Rs x 10^9 of 1970
TX	Tax	Rs x 10^9 of 1970
IG	Government investment	Rs x 10^9 of 1970
I	Total investment	Rs x 10^9 of 1970
IF	Gross fixed investment	Rs x 10^9 of 1970
IR	Investment for the replacement of depreciated capital stock	Rs x 10^9 of 1970
JAG	Investment in the agricultural sector	Rs x 10^9 of 1970
INA	Investment in the nonagricultural sector	Rs x 10^9 of 1970
X	Exports	Rs x 10^9 of 1970
M	Imports	Rs x 10^9 of 1970
M_{0-9}	Imports of goods of SITC[b] sectors 0 to 9	Rs x 10^9 of 1970
M_{245-9}	Nonfuel imports of goods	Rs x 10^9 of 1970
F	Foreign aid	Rs x 10^9 of 1970
*F$**	Foreign aid	current U.S. $ x 10^9
*TFP$*B*	Private transfers to India	current U.S. $ x 10^9
N	Population	x 10^6
NU	Urban population	x 10^6
FREL	Fraction of villages supplied with electricity	x 10^3

Appendix B continued.

Symbol	Variable	Unit
PCOAL	Capital required for coal	Rs of 1970
FOILD	Fraction of oil domestically produced	–
ET	Total energy	10^6 tce, 5,000 kcal/kg
EC	Commercial energy	10^6 tce, 5,000 kcal/kg
ENC	Noncommercial energy	10^6 tce, 5,000 kcal/kg
EEL	Electrical energy	10^6 tce, 5,000 kcal/kg
EKW	Power capacity required	kW x 10^6
TCOAL	Total annual coal production, including coal required for electricity generation	tons x 10^6
OIL	Oil requirement	tons x 10^6
OILD	Domestically produced oil	tons x 10^6
OILM	Imported oil	tons x 10^6
KE	Capital for energy	Rs x 10^6 of 1970
YDPC	GDP, per capita	Rs of 1970
CPPC	Private consumption, per capita	Rs of 1970
CG	Government consumption, per capita	Rs of 1970
ETPC	Total energy, per capita	tce, 5,000 kcal/kg
ECPC	Commercial energy, per capita	tce, 5,000 kcal/kg
EELPC	Electrical energy, per capita	tce, 5,000 kcal/kg

[a] The symbols presented here differ slightly from those given in the text.
[b] SITC is the abbreviation of Standard International Trade Classification.

Appendix C

CLARIFICATION OF ENERGY CONSUMPTION DATA IN INDIA

Because of the conventions used in India, there is often a confusion about India's data on energy use. There are errors in the Fuel Policy Committee Report in India and in the reports of the United Nations. Therefore, we have attempted to clear up the confusion.

FUEL POLICY COMMITTEE (FPC) REPORT

Electricity consumption should be the same in coal replacement units as in coal equivalent units (tce). But electricity in terms of coal equivalent units should have the relation

$$1{,}000 \text{ kWh} = 0.172 \text{ tce (Indian coal with 5,000 kcal/kg)}.$$

If, however, one considers the efficiency factor on the basis of that of 1970, when 17×10^6 tons of coal were used to generate 28×10^9 kWh of electricity, then, in terms of coal consumed, 1,000 kWh = 0.6 tce. The FPC equation, 1,000 kWh = 1 tce, is, therefore, not used. For this reason our figures for energy consumption in India, especially for commercial energy, are lower than in the FPC.

WORLD ENERGY SUPPLIES OF THE UNITED NATIONS

World Energy Supplies (WES) takes the original units of each resource and multiplies them by the appropriate calorific content to obtain coal equivalent units. However, in doing so, the fact that coal in India has 5,000 kcal/kg is not considered, whereas the WES data takes the calorific value of coal to be 7,000 kcal/kg. India is, therefore, reported to have a higher energy consumption than it has in reality. The conventions used in stating energy consumption at different points in time may be seen in Tables D.1 to D.3.

Appendix D

THE DETAILED RESULTS OF SCENARIOS

TABLE D.1 Lower incremental capital/output ratio in nonagriculture.

	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	1.RATE	2.RATE
YA/YD	0.42	0.36	0.32	0.29	0.26	0.23	0.22	0.22	0.23	0.22	0.20	0.18	-2.33	-1.48
YD	457.79	606.76	794.90	1027.54	1329.03	1727.48	2093.94	2420.34	2701.09	3286.73	4116.41	5277.42	5.46	4.55
YA	[illegible]	221.22	256.45	297.30	344.65	399.55	463.18	536.96	622.48	721.63	836.56	969.81	3.00	3.00
YNA	231.23	336.52	471.85	642.95	872.69	1181.16	1452.39	1676.48	1846.81	2281.90	2922.83	3850.74	6.74	5.25
C	361.35	492.45	635.05	811.85	1059.11	1342.95	1621.58	1872.22	2090.23	2538.92	3171.43	4051.97	5.16	4.39
CP	326.00	419.53	538.43	686.08	875.68	1129.37	1357.02	1563.92	1743.73	2124.53	2654.29	3389.95	5.07	4.34
CG	53.45	72.93	96.26	125.13	163.34	212.83	264.73	308.40	345.80	412.22	514.72	661.23	5.68	4.68
TX	64.94	89.22	118.30	154.30	201.93	263.61	328.32	362.75	429.37	512.17	639.95	822.58	5.76	4.72
IG	35.40	43.32	55.20	69.91	89.37	110.58	141.02	163.26	182.31	216.14	268.35	342.97	5.05	4.33
I	83.43	122.26	167.30	221.07	289.78	378.20	449.53	501.87	533.90	648.95	819.32	1064.78	6.24	4.74
IF	74.05	106.13	147.77	203.06	275.36	359.96	426.97	476.71	507.91	618.75	781.19	1012.42	6.53	4.87
IAG	19.65	16.75	23.51	29.02	35.41	42.82	51.41	61.37	72.92	86.30	101.82	119.81	4.39	3.90
INA	52.00	76.76	109.49	153.74	212.59	281.94	332.59	367.45	384.73	472.16	602.71	791.43	7.00	5.07
INV	9.16	16.13	19.91	18.53	14.32	18.04	22.70	25.30	26.01	30.21	38.62	52.85	2.75	3.24
IR	7.41	10.61	14.78	20.31	27.55	36.04	42.68	47.66	50.83	61.98	78.22	101.25	6.53	4.87
X	19.71	25.15	32.10	40.97	52.29	66.73	85.17	108.70	138.73	177.06	225.98	288.41	5.00	5.00
PX	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	00.00	00.00
PU	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	00.00	00.00
F	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	5.36	00.00	00.00
TFP	2.00	3.60	3.97	4.39	4.85	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.73	1.68
YF	0.06	0.34	0.62	0.90	1.18	1.46	1.74	2.02	2.31	2.59	2.87	3.15	13.92	7.59
M	26.87	33.10	38.71	45.01	52.11	59.58	62.45	62.44	60.79	75.59	96.64	126.18	3.24	2.85
PMOIL	571.20	630.65	696.29	768.76	848.77	937.11	1034.65	1142.34	1260.00	1260.00	1260.00	1260.00	2.02	1.45
MOIL	7.08	5.32	8.64	12.91	17.85	23.89	36.93	52.46	68.86	87.41	109.54	135.48	4.99	5.51
M245-9	14.63	20.42	24.15	26.75	29.93	33.47	29.92	24.21	18.08	21.61	28.67	40.70	3.37	1.88
YDPC	745.69	889.02	1057.30	1250.55	1490.72	1804.06	2050.66	2241.03	2382.08	2778.98	3355.28	4165.79	3.60	3.18
CPPC	534.43	614.69	715.88	834.70	982.30	1179.69	1328.85	1447.95	1537.87	1796.72	2163.56	2675.72	3.22	2.97
CGPC	87.11	106.85	127.89	152.09	183.21	222.16	259.27	285.55	304.85	348.26	419.18	521.79	3.82	3.31
ETPC	0.50	0.55	0.59	0.64	0.68	0.74	0.77	0.80	0.81	0.86	0.92	1.00	1.53	1.25
ECPC	0.18	0.24	0.30	0.36	0.43	0.50	0.55	0.59	0.62	0.68	0.76	0.85	4.17	2.85
ENCPC	0.32	0.31	0.29	0.27	0.25	0.23	0.22	0.20	0.19	0.18	0.16	0.15	-1.29	-1.42
ELLPC	0.02	0.03	0.04	0.05	0.07	0.08	0.09	0.10	0.10	0.11	0.13	0.14	5.91	3.71
ET	309.46	374.03	445.43	522.78	608.94	706.32	789.02	859.28	917.29	1012.97	1127.71	1262.54	3.36	2.59
EC	111.25	163.51	226.90	299.35	383.32	482.55	566.31	638.87	700.14	804.41	929.41	1075.90	6.05	4.21
ENC	198.14	210.52	218.71	223.68	225.63	223.95	222.67	220.40	217.28	208.84	198.58	186.74	0.49	-0.11
ELL	11.68	19.79	30.63	43.64	58.81	76.67	91.51	104.04	114.19	132.01	153.53	178.98	7.82	5.09
NEL	99.52	143.72	196.37	255.66	324.53	406.03	474.75	534.82	586.04	672.62	776.06	896.99	5.79	4.08
OIL	20.40	24.43	33.39	43.51	55.17	69.05	80.70	90.92	99.64	114.37	131.95	152.50	5.00	3.73
OILD	8.00	16.00	21.00	26.74	34.13	43.56	45.00	45.00	45.00	45.00	45.00	45.00	7.01	3.19
OILM	12.39	8.43	12.40	16.78	21.04	25.50	35.70	45.92	54.65	69.38	86.95	107.51	2.93	4.01
KOR	4.30	3.69	3.29	3.03	2.86	2.76	2.69	2.64	2.61	2.59	2.57	2.56	-1.80	-0.95
KORA	2.56	2.83	3.06	3.25	3.42	3.57	3.70	3.81	3.90	3.99	4.06	4.12	1.34	0.87
N	613.55	682.51	752.64	822.72	691.55	957.98	1021.06	1060.02	1134.32	1183.66	1227.93	1267.23	1.80	1.33
NU	132.39	159.65	190.85	226.15	265.66	309.45	357.55	409.97	466.77	528.01	593.79	664.30	3.45	2.98
NR	481.16	522.86	561.79	596.57	625.88	648.53	663.52	670.05	667.55	655.65	634.14	602.93	1.20	0.41
FREL	287.17	428.20	581.96	721.28	827.90	899.42	943.26	968.65	982.89	990.72	994.99	997.30	4.67	2.29

TABLE D.2 Higher agricultural growth rate and lower incremental capital/output ratio.

	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	1.RATE	2.RATE
YA/YD	0.42	0,39	0.36	0,33	0,31	0,29	0,27	0,25	0,26	0,26	0,25	0,24	-1,54	-1,00
YD	462.66	613,10	809.46	1055,24	1305.71	1808,60	2368,74	3021,77	3547,51	4357,44	5449,93	6932,35	5,62	5,85
YA	194.55	236,70	287.98	350.37	426.28	516.64	631,00	767.71	934,03	1136,40	1382,60	1682.14	4.00	4,00
YNA	229.76	326,83	454,79	617.21	842.51	1137,61	1530,98	1994,03	2309,93	2846,16	3594,99	4651.60	6,61	5.62
C	364.38	499,77	648,79	835,37	1088,26	1408,84	1840,08	2335,53	2736,33	3356,11	4191,36	5314,89	5,33	4,89
CP	330,90	426,67	552,28	709,03	920.78	1189,62	1550,46	1958,33	2293,47	2818,68	3518,61	4464,39	5,25	4,84
CG	53,55	73,10	96,56	126,72	167,04	219,42	288,02	376,72	443,60	537,37	671,89	852,80	5,80	5.16
TX	65,06	89,44	118,68	156,27	206.54	271,83	357,35	467,92	551,29	668,18	835,88	1061,39	5,89	5.21
TG	33,58	44,23	56,98	73,27	94,89	122,82	159,21	206,08	242,09	292,11	363,26	458,44	5,32	4,87
I	83,51	122,28	169,21	226.42	301,65	397.15	521,61	661,59	753,40	921,65	1154,37	1479.19	6,44	5.36
IF	74,48	108,31	152,31	213,13	286.96	376,89	497,36	629,25	714,97	875,51	1097,61	1403,86	6,70	5,48
IAG	20,05	27,64	36,87	48,10	61,77	78,39	98,61	123.22	153,16	189,59	233,90	287,82	5,60	4,96
INA	46,98	69,84	100,21	143,71	197.00	260,69	349,59	443,35	489,76	598,34	754,00	973,02	7,09	5,67
INV	8,98	13,97	16,90	13,14	14,55	20,08	25,02	32,59	38,36	46,12	57,33	76,40	3,27	3,97
IR	7,45	10,83	15,23	21,31	28.73	37,68	49,78	62,94	71,46	87,55	109,77	140,24	6,70	5,48
X	19,71	25,15	32,10	40,97	52.29	66,73	85,17	108,70	138,73	177,06	225,98	288,41	5,00	5,00
PX	1,00	1,00	1.00	1.00	1.00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	00,00	00,00
PM	1,00	1,00	1.00	1.00	1.00	1,00	1.00	1,00	1,00	1,00	1,00	1,00	00,00	00,00
F	5.52	6.40	7,42	8,60	9,97	11.55	13,39	15,53	18,00	20,87	24,19	28,04	3,00	3,00
TFP	2,00	3,60	3,97	4,39	4.85	5,00	5.00	5,00	5,00	5,00	5,00	5,00	3,73	1,68
YF	0,06	0,36	0,72	1,13	1.61	2.17	2,81	3,56	4,42	5,43	6,59	7,94	15,73	9,42
M	27,02	34,10	40,65	48,00	56,02	64,81	74,72	83,04	82,15	97,44	119,92	152,14	3,56	3,19
PMOIL	571,20	630,65	696,29	768,76	848,77	937,11	1034,65	1142,34	1260,00	1260,00	1260,00	1260,00	2,00	1,45
MOIL	7,18	5,41	8,70	12,90	18.39	24,15	30,68	41,05	60,04	79,97	102,91	128,85	4,97	5,39
M245-9	14,62	20,66	25,51	28,96	32,74	37,17	43,04	46,39	38,92	42,34	50,24	64,15	3,80	2,73
YDPC	750,67	898,29	1075,49	1282,06	1554,77	1887,28	2323,24	2798,78	3126,43	3681,33	4439,80	5469,03	3,76	3,68
CPPC	539,21	625,14	733,72	861,36	1033,28	1241,59	1520,04	1813,68	2021,24	2381,39	2866,17	3521,13	3,39	3,47
CGPC	87,28	107,11	128,30	154,02	187.36	229,04	282,08	348,81	391,07	453,99	547,18	672,97	3,93	3,78
ETPC	0,50	0,54	0,58	0,63	0,68	0,73	0,79	0,84	0,87	0,92	0,98	1,06	1,48	1,36
FCPC	0,18	0,24	0,30	0,36	0,43	0,50	0.58	0,66	0,70	0,76	0,84	0,93	4,14	3,00
FNCPC	0,32	0,30	0,28	0,26	0,24	0,22	0,20	0,19	0,17	0,16	0,15	0,13	-1,44	-1,60
FELPC	0,02	0,03	0,04	0,05	0,07	0,08	0,09	0,11	0,11	0,12	0,14	0,15	5,80	3,83
FT	309,07	370,80	439,98	515,30	602,42	697,25	804,27	910,72	987,72	1089,84	1208,05	1344,15	3,31	2,71
EC	112,21	164,28	227,30	299,09	386,20	483,07	595,78	707,69	790,21	901,27	1029,58	1176,32	6,01	4,36
FNC	196,84	206,52	212,66	216,08	216.34	214,10	208,90	203,11	197,38	188,58	178,61	167,60	0.34	-0,29
FEL	11,75	19,70	30,25	42,61	58,21	75,17	94,81	113,94	127,32	145,72	167,11	191,71	7,71	5.21
NEL	100,43	144,57	197,03	256,17	328,10	407,86	501,20	593,79	662,80	755,57	862,56	944,38	5,77	4,24
OIL	20,58	24,58	33,49	43,53	55,79	69,33	85,23	100,94	112,66	128,45	146,65	167,31	4,98	3,88
OILD	8,00	16,00	21,00	26,74	34,13	43,56	55,59	65,00	65,00	65,00	65,00	65,00	7,01	3,86
OILH	12.58	8,58	12,49	16,78	21.67	25,78	29,65	35,94	47,65	63,46	81,66	102,28	2,91	3,86
KOR	4,35	3,73	3,33	3,07	2,89	2,77	2,70	2,64	2,61	2,58	2,57	2,55	-1,79	-0,97
KORA	2,58	2,92	3,20	3,43	3,62	3,78	3,91	4,01	4,10	4,17	4,23	4,28	1,54	0,93
N	613,55	682,51	752,64	822,72	891,55	957,98	1021,66	1080,02	1134,32	1183,66	1227,93	1267,23	1,80	1,33
NU	132,39	159,65	190,65	226,15	265,66	309,45	357,55	409,97	466,77	528,01	593,79	664,30	3,45	2,98
NR	481,16	522,86	561,79	596,57	625,88	648,53	663,52	670,05	667,55	655,65	634,14	602,93	1,20	0,41
FREL	287,17	428,20	581,96	721,25	827,90	899,42	943,26	968,65	962,89	990,72	994,99	997,30	4,67	2,29

TABLE D.3 Increasing aid, higher agricultural growth rate, and lower incremental capital/output ratio.

	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	1.RATE	2.RATE
YA/YD	0.42	0.36	0.31	0.27	0.23	0.20	0.17	0.15	0.12	0.11	0.09	0.07	-2.95	-3.08
YD	463.82	661.57	924.82	1303.59	1851.45	2620.03	3684.45	5264.77	7510.89	10600.69	15282.24	22441.72	7.17	7.31
YA	194.55	236.70	287.98	350.37	426.28	518.64	631.00	767.71	934.03	1136.40	1382.60	1682.14	4.00	4.00
YNA	231.92	371.16	558.78	843.77	1266.05	1878.19	2739.46	4042.69	5929.12	8546.54	12572.19	18805.10	8.73	8.32
C	362.82	497.22	681.77	940.35	1327.37	1864.72	2613.94	3726.78	5299.10	7469.26	10761.32	15796.64	6.77	7.10
CP	309.42	419.88	571.13	788.11	1103.00	1544.73	2158.77	3070.19	4356.71	6134.47	8834.27	12960.97	6.64	7.03
CG	53.17	77.52	110.20	156.79	225.27	321.74	455.54	655.41	943.32	1336.28	1928.15	2835.53	7.47	7.50
TX	96.88	142.41	203.52	290.63	418.69	599.07	849.26	1222.98	1761.34	2496.12	3602.83	5299.51	7.56	7.55
IG	46.58	65.87	91.65	128.17	181.58	256.53	360.21	514.59	736.52	1039.01	1493.83	2190.13	7.06	7.25
I	108.93	173.12	252.27	360.19	522.83	741.93	1040.03	1483.21	2115.92	2987.44	4321.05	6380.89	7.98	7.68
IF	93.91	148.74	229.90	345.53	496.04	703.26	987.24	1409.52	2008.70	2837.21	4105.38	6060.73	8.39	7.87
IAG	20.05	27.60	36.87	48.10	61.77	78.39	98.61	123.22	153.16	189.59	233.90	287.82	5.60	4.96
INA	64.47	106.23	170.07	262.20	383.68	552.94	789.70	1146.99	1653.85	2361.80	3454.01	5166.97	8.98	8.30
INV	15.26	24.31	22.71	18.85	27.15	38.98	52.39	72.93	107.02	151.19	217.91	320.20	3.82	5.69
IR	9.39	14.87	22.99	34.52	49.55	70.23	98.71	141.03	200.81	283.61	410.40	606.33	8.38	7.87
X	20.08	28.17	39.50	55.41	77.71	108.99	152.87	214.40	300.71	421.77	591.55	829.68	7.00	7.00
PX	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	00.00	00.00
PM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	02.00	00.00
F	5.52	6.40	7.42	8.60	9.97	11.55	13.39	15.53	18.00	20.87	24.19	28.04	3.00	3.00
TFP	2.00	3.60	3.97	4.39	4.85	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.73	1.68
YF	0.06	0.36	0.72	1.13	1.61	2.17	2.81	3.56	4.42	5.43	6.59	7.94	15.73	9.42
M	27.42	37.12	47.70	60.89	77.23	97.54	123.82	158.53	206.49	278.97	391.03	561.23	5.21	5.64
PMOIL	571.20	630.65	696.29	768.76	848.77	937.11	1034.65	1142.34	1260.00	1260.00	1260.00	1260.00	2.00	1.45
MOIL	6.16	5.41	10.16	17.05	26.49	38.30	52.51	70.21	90.10	130.40	178.27	234.63	7.58	6.84
M245-9	15.92	24.64	30.05	36.25	44.25	55.05	70.12	92.73	124.96	164.91	233.22	344.34	5.09	5.75
YDPC	756.92	969.06	1230.11	1583.86	2075.83	2732.98	3607.20	4875.55	6620.13	8955.01	12446.20	17712.79	5.27	5.90
CPPC	504.69	614.95	759.42	957.27	1236.16	1610.65	2113.88	2843.81	3839.99	5181.38	7193.53	10227.91	4.75	5.62
CGPC	86.65	113.57	146.42	190.57	252.67	335.85	446.14	606.84	831.61	1128.94	1570.24	2237.58	5.57	6.09
ETPC	0.50	0.55	0.61	0.68	0.75	0.84	0.93	1.04	1.16	1.30	1.46	1.65	2.12	2.22
ECPC	0.17	0.24	0.32	0.41	0.51	0.62	0.73	0.87	1.01	1.16	1.34	1.55	5.38	4.14
ENCPC	0.33	0.31	0.29	0.27	0.24	0.22	0.20	0.18	0.16	0.14	0.12	0.11	-1.61	-2.03
EELPC	0.02	0.03	0.04	0.06	0.08	0.10	0.12	0.14	0.17	0.20	0.23	0.27	7.18	5.07
ET	303.60	376.70	459.03	556.21	671.05	801.88	949.46	1123.70	1319.72	1535.53	1792.47	2097.11	3.96	3.58
EC	102.16	164.69	241.96	337.62	455.32	592.14	748.56	934.36	1142.64	1371.50	1642.78	1962.23	7.28	5.52
ENC	201.60	211.94	217.27	218.43	215.52	209.44	200.81	189.53	177.03	163.92	149.61	134.84	0.15	-0.73
EEL	10.70	19.98	32.80	49.51	70.51	95.03	122.96	155.99	192.79	233.09	280.92	337.27	9.11	6.47
NEL	91.52	144.65	209.26	287.97	384.62	496.88	625.57	778.55	949.84	1138.30	1361.76	1624.88	7.00	5.37
OIL	18.78	24.58	35.59	48.94	65.36	84.44	106.35	132.38	161.48	193.50	231.48	276.21	6.20	5.01
OILD	8.00	16.00	21.00	26.74	34.13	43.56	55.59	70.95	90.00	90.00	90.00	90.00	7.01	4.50
OILM	10.78	8.58	14.59	22.19	31.21	40.87	50.75	61.46	71.49	103.49	141.08	186.21	5.47	5.32
KOR	4.28	3.55	3.13	2.89	2.75	2.66	2.61	2.57	2.55	2.53	2.52	2.52	-1.88	-0.96
KORA	2.58	2.92	3.20	3.43	3.62	3.78	3.91	4.01	4.10	4.17	4.23	4.28	1.54	0.93
N	613.55	682.51	752.64	822.72	891.55	957.98	1021.06	1080.02	1134.32	1183.66	1227.93	1267.23	1.80	1.33
NU	132.39	159.65	190.85	226.15	265.66	309.45	357.55	409.97	466.77	528.01	593.79	664.30	3.45	2.98
NR	481.16	522.06	561.79	596.57	625.88	648.53	663.52	670.05	667.55	655.65	634.14	602.93	1.20	0.41
FREL	287.17	428.20	581.96	721.20	827.90	899.42	943.26	968.65	982.89	990.72	994.99	997.30	4.67	2.29

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