A MODEL FOR THE PROJECTION OF ENERGY DEMAND IN MAURITIUS

A Y Maudarbocus
University of Mauritius

ABSTRACT

This study sets out to develop a simple econometric model, using electronic spreadsheet analysis, to predict the sectoral and aggregate energy demand of Mauritius until the year 2000. The model is tested for an activity annual growth rate of 3 to 4% and an annual rate of fuel price increase of 5 to 8%. The results indicate that, excluding the sugar sector, some 350,000 TOE of primary energy input would be required annually by the year 2000, a figure far lower than most, if not all, previous estimates. The implications for investment in new capacity are quite important.

INTRODUCTION

Energy planning requires a reasonable knowledge of past energy consumption and a projection of likely future consumption. The most powerful tool for studying energy demand is econometric modelling. This approach uses statistical methods to estimate demand functions in accordance with the economic theory of demand. Econometric methods may be applied at any level of disaggregation, for example total demand, demand for each fuel, and sectoral demand.

This study is concerned with long-term forecasts of energy demand using the econometric approach. The economic parameters income and price elasticities, to be used in the energy demand functions, are derived from historical data. Thus the first part of this study is devoted to the establishment of the energy balance of Mauritius for the period of 1975 to 1983.

THE ENERGY BALANCE

Units

In an energy balance table, it is necessary to convert measurement of all the different fuels to a common basis. Tonnes oil equivalent (TOE) is used in the present study, not only because it is becoming the most universally used energy unit, but also because the primary concern of energy planners in the non-oil producing developing world is to minimise oil imports.

The sugar sector

In Mauritius, the sugar industry, which consumes more than half of the primary energy input, is self-sufficient energy-wise, using bagasse, a by-product of sugar-processing, for all its energy requirements. Energy production and consumption in the sugar sector have been excluded from the energy balance here. However, provision is made for the electricity purchased from the sugar factories for the national grid.

Level of disaggregation

An energy balance is a set of equilibrium relationships to describe the energy supply, conversion and consumption at a point in time. The energy balance is represented as a matrix or table. The data for different fuel types are disaggregated and the energy consumption is considered separately for the industrial, transport, domestic and commercial sectors.

The primary energy supply is broadly sub-divided into indigenous products and imports, the latter consisting of petroleum products and coal, whereas hydro and bagasse make up the bulk of the indigenous products. The primary energy content of the hydro and bagasse is evaluated on an oil equivalent basis, assuming a conversion efficiency of 33%. The contribution of fuel wood and wood charcoal, which, according to Gillett (1981), accounts for only about 0.5% of the total primary energy input has not been considered because of lack of reliable data. It has also not been possible to obtain consistent data for stock exchange of petroleum products.

Assumptions and computerisation

With the available data, sets of equilibrium relationships are established on the basis of certain assumptions. For example, it is assumed that:

a. Kerosene and LPG are used exclusively for domestic purposes
b. Gasoline is used exclusively for transportation
c. Diesel is used for electricity generation and transportation
d. Fuel oil is used for electricity generation and industry
e. Electricity is the only energy input in the commercial sector.

An Electronic Spreadsheet - Multiplan - is used for tabulation and computation. By properly "linking" the various "cells" of the spreadsheet with the appropriate formulae, it only becomes necessary to enter the data, and the computer takes care of all the calculations and displays the values in the appropriate places.

General comments on the energy balance

The energy balance for Mauritius for 1975-83 was computed largely following the format recommended by Meier (1983). A summary of sectoral energy consumption, 1975-83, is presented in Table 1.

Excluding the sugar sector, imported petroleum products account for about 90% of the total primary energy input. This figure has remained virtually constant for the past decade.

The total primary energy supply, increased annually by about 10% during the period 1975 to 1979, and has since declined gradually by about 3% annually.

The production of electricity for the national grid has only been growing at a rate of about 1% annually since 1979.

The transport sector has been by far the largest consumer of energy, accounting for about 60% of total final energy use. The transport sector uses only petroleum products, while all other sectors use at least a certain proportion of high grade energy in the form of electricity. Had the comparison been done instead on the basis of primary energy inputs, the transport sector could have been shown to consume about 50% of the total primary energy input.

THE ECONOMETRIC MODEL

The econometric equation

Energy demand for a particular fuel, i, can be assumed to be a function of:

a. Economic activity, A, (eg GDP).
b. Price of the fuel i, P_i.
c. Price of other substitutes to fuel i, $P_j \neq i$.
d. A time factor $\emptyset(t)$.
e. Physical factors (eg temperature).

As we are here dealing with only one country, the physical factors are ignored. Further, in the present study, the time factor and the effect of fuel substitutes are not considered. With these assumptions, the demand function, D_i, of fuel, i, becomes

$$D_i = f(A, P_i) \tag{1}$$

A widely used demand function is of the log-linear type. Thus

$$D_i = K\, A^{\alpha}\, P_i^{\beta} \tag{2}$$

where α is the income elasticity and β the price elasticity coefficient of energy demand.

If the activity growth rate is r and the annual increase in fuel price p, then the energy demand after one year, D_1, relative to the energy consumption, D_o, for a base year is given by

$$D_1 = D_o\,(1+r)^{\alpha}\ (1+p)^{\beta} \tag{3}$$

thus energy demand after the nth year is

$$D_n = D_o \left\{(1+r_1)\,(1+r_2)\,.....\,(1+r_n)\right\}^{\alpha} \left\{(1+p_1)\,(1+p_2)\ (1+p_n)\right\} \tag{4}$$

The income elasticity, α , and price elasticity, β , are derived from the historical data contained in Table 1, using the ratio of GDP to consumer price index as a measure of activity, A. The actual values of A, r and p used for the calculation of α and β by linear regression methods are shown in Table 2.

Sectoral energy demand forecast

Energy demand forecasts to 2000 are summarised in Table 3 and Figure 1, taking 1983 as the base year.

For the transport and industrial sectors α and β were calculated at 1.15 and -0.20 respectively. It was assumed that there would be an activity annual growth rate of 3% until 1990, 3.5% until 1995 and finally 4% until the year 2000, as well as a rate of fuel price increase of 5% annually until 1990 and 8% thereafter.

Given these assumptions it is forecast that the transport sector will require some 143,000 toe annually as primary energy input by the year 2000 and the industrial sector will have a two-fold increase in energy requirements by the year 2000 (Table 3, Figure 1).

The projection of energy demand for the commercial and domestic sectors has been computed on the assumption that $\alpha = 1$.

Projection of total energy demand

The sectoral energy demand for each year is aggregated to the total energy demand as illustrated in Figure 1. The model indicates that the aggregate energy demand for the year 2000 would be slightly less than 250,000 TOE. When allowance is made for conversion losses, the total primary energy input required would be of the order 250,000 TOE for 1990 and about 340,000 TOE for the year 2000. These figures are very low when compared to previous estimates; for example, a World Bank/UNDP study (Ahmed et al 1981) indicates that the primary energy requirements for the year 1990 would be of the order of 295,000 to 330,000 TOE, which far exceeds our estimate.

A rough estimate also indicates that petroleum requirements for the year 2000 would be about 290,000 TOE.

CONCLUSIONS

Any forecast will be at best an approximation to an unforeseeable future. However, provided there is a reasonable amount of accurate data, econometric methods have been known to yield fairly accurate forecasts.

In the present study, it can be argued that the econometric parameters such as income and price elasticity coefficients derived from historical data may not be appropriate for the projection model. Similarly, the assumptions regarding activity growth rate and estimated increases in fuel price may be questioned. However, the beauty of electronic spread-sheet analysis is that all computed values of the energy balance table automatically adjust themselves once any parameter (or any other data) is changed. The above exercise can therefore be carried out for any other assumptions or scenarios, without sacrificing time. In fact this method lends itself very appropriately to "what-if" analysis and close monitoring.

Despite the uncertainties inherent in any projection exercise, our estimates of energy demand fall far short of all previous estimates. The far-reaching implications of heavy investment in new capital equipment should therefore be looked into more judiciously.

With the exception of the sugar industry, the transport sector will remain the main consumer of energy. In order to reduce our dependence on imported fuel appreciably, the production of indigenous substitutes should be seriously considered.

Although the present econometric model has been applied specifically to Mauritius, it can be easily adapted to any other country.

ACKNOWLEDGEMENT

I wish to place on record the valuable contribution of Dr Ray Tomkins, of the Management Science Department, Imperial College of Science and Technology, University of London, for his advice and suggestions to use electronic spreadsheet analysis.

REFERENCES

Ahmed M et al (1981) Mauritius: issues and options in the energy sector. UNDP/World Bank Report No 3510-MAS.

Gillett W B (1981) A second visit to the University of Mauritius. UCC Report No 286. University College, Cardiff, Wales.

Meier P M (1983) Institutional analysis of the energy policy and projects division. Ministry of Energy, Mauritius.

TABLE 1: Sectoral Energy Consumption - 1975 to 1983

(All units in TOE)

Energy Sector	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**
Industrial	14,215	21,030	22,930	24,960	23,263	22,865	22,250	21,740	21,140
Domestic	24,890	29,465	34,625	38,560	39,451	36,614	30,410	30,480	29,650
Commercial	4770	4795	4950	5480	6060	5865	6060	6430	6480
Transport	80,810	90,680	100,105	104,120	102,123	91,040	97,970	90,780	91,995
Total energy use	124,685	145,970	162,610	173,120	170,897	156,384	156,690	149,430	149,265
Total primary energy supply	163,925	192,910	216,640	230,560	232,940	214,505	213,880	207,590	206,145

TABLE 2: Some Economic Parameters used to evaluate Income elasticity (α) and price elasticity (β)

Year	GDP (at factor cost) Rs Million	$A = \frac{GDP}{CPI}$	Growth Rate r	Rate of fuel price increase p
1975	3090	2687	-	-
1976	3666	2864	0.066	0.21
1977	4357	3090	0.079	0.05
1978	4875	3186	0.031	0.02
1979	6540	3737	0.173	0.37
1980	7389	2979	-0.203	0.95
1981	8765	3086	0.036	-
1982	10,050	3160	0.024	-
1983	10,650	3170	0.003	-

TABLE 3: Sectoral Energy Demand Forecast until the Year 2000

(All Units in TOE)

Sector	**1983**	**1985**	**1990**	**1995**	**2000**
Industrial	21,140	22,600	26,800	32,000	40,000
Domestic	29,650	31,400	36,400	43,000	52,000
Commercial	6480	6900	8000	9500	11500
Transport	91,995	97,500	109,000	123,000	143,000
Total energy demand	**149,265**	**158,400**	**180,200**	**207,500**	**246,500**
Required total Primary Energy Supply (incl. conversion losses)	206,000	218,600	248,600	288,400	342,600
Total energy supply* UNDP/WB (1981) AEP Scenario		255,000	295,000		
BC Scenario		270,000	330,000		
Required petroleum products	**189,000**	**186,000**	**211,000**	**245,000**	**290,000**

* Figures given for comparison purposes From Ahmed <u>et al</u> (1981).

FIGURE 1: Sectoral Energy Demand Forecast