The Pakistan Development Review
Vol. XXIII, Nos. 2 & 3 (Summer-Autumn 1984)

Pakistan: Energy Consumption and Economic Growth

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INTRODUCTION

After the Arab oil embargo of 1973, oil prices rose rapidly and the energy-importing economies experienced an exogenously determined real supply shock, which, in most cases, led to a fall in their rates of economic growth and a corresponding rise in the rates of inflation.[1] The energy situation emerged as a serious issue and the relationship between energy consumption and economic growth came into sharp focus. The last decade has been a period of disequilibrium, structural adjustment and adoption of strategies to cope with the previously unknown phenomenon of stagflation.

This paper sets out first to establish a relationship between energy consumption and economic growth with specific reference to Pakistan. Then it estimates Pakistan's future energy demand which is consistent with the historical, social and economic progress of the country and is unconstrained by energy availability. Secondly, it develops an integrated energy sector plan and partially links it with the rest of the economy. Finally, an explicit energy–economy interaction framework is developed to assess inter-linkage impact and to make policy inferences.

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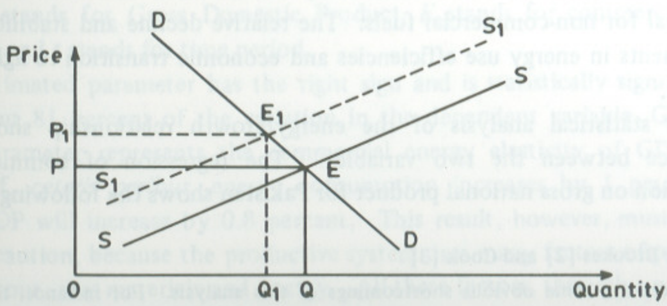
[1] The impact of supply can be studied by using a simple demand-supply diagram.



The exogenous supply shock shifts the supply curve SS to a new position $S_1 S_1$; which leads to a new equilibrium at E_1. At the new equilibrium price is higher and the output lower than at E.

ENERGY AND ECONOMIC GROWTH

Man has used a variety of energy sources in his long involvement in the pursuit of greater comfort, enhanced security and satisfaction of wants through the medium of increasingly elaborate artifacts. Energy has played a vital role in taking man from the Stone Age to the supersonic era.

Historically, energy consumption has closely matched changes in gross domestic product. There is an obvious reason. The basic production system of an economy uses domestic and foreign resources of capital, labour, energy and raw materials in combination with technical knowledge to transform them into goods and services. The market value of these outputs produced in a given time period form the gross domestic product of a country and when foreign earnings are added to this sum, it turns into gross national product. These goods and services are available to satisfy the demands of consumers, producers, government and exporters. The levels of output and employment are constrained by the availability of inputs and the efficiency of the technology. At the same time, these levels also depend on the effective demand for goods and services.

A scattergram of GNP-Energy data for a number of countries and for various years is given by a number of sources.[2] Most rich countries in these diagrams fall into the top right hand corner, whereas most poor countries including Pakistan are placed in the bottom left-hand corner. The placing position of various countries indicates a strong correlation between energy and economic growth. The top right-hand corner reflects high income, high energy consumption, whereas the bottom left corner shows low income, low energy consumption. The scatter is diagonal and fairly narrow. However, it must be remembered that the sample is not random and therefore the statistical inference may not be justified.

The energy-output ratios for a number of countries also show a common trend – that in the early stages of economic growth, these go up and once the country has gained industrial maturity, the ratio declines slightly and then settles down at a fairly high level. The increase in the magnitude of the ratio can be explained in terms of industrialization, urbanization and the substitution of commercial for non-commercial fuels. The relative decline and stability result from improvements in energy use efficiencies and economic transition to light and service industries.

The statistical analysis of the energy/growth relationship shows an interdependence between the two variables. The regression of commercial energy consumption on gross national product for Pakistan shows the following result.[3]

[2]See Brookes [2] and Cook [3].

[3]There are some obvious shortcomings of this analysis. For instance, the exclusion of non-commercial energy, the conversion of all commercial fuels to a common denominator which takes no account of a fuel's efficiency, etc. The data for these estimates have been obtained from the Government of Pakistan [7;8].

$$\log E_t = 0.3697 + 1.2274 \log GNP_t \quad \ldots \quad \ldots \quad \ldots \quad (1.1)$$

$$\text{St. error} = (0.0264)$$
$$t\text{-ratio} = (40.42)$$
$$R^2 = 0.992 \qquad \bar{R}^2 = 0.991$$

where E stands for commercial energy consumption, GNP stands for Gross National Product and t stands for time period.

The intercept in (1.1) is negative and slope positive. The coefficient is statistically significant. The estimated parameter is the income elasticity of 1.2274, which means that if, *ceteris paribus*, gross national product increases by 1 percent, then commercial energy consumption rises by 1.23 percent. The correlation between commercial energy consumption and GNP is very high indeed, i.e. 0.99.

The negative intercept and positive slope shown in (1.1) is consistent with the hypothesis that at an early stage of economic development each country relies heavily on non-commercial sources of energy and that the subsequent process of industrialization and urbanization is highly energy-intensive. In statistical terms, one should expect a negative intercept and a positive slope for a developing country like Pakistan, whereas a developed country would be expected to have a positive intercept and positive slope which is fairly shallow as it must use large amounts of commercial energy to sustain itself – but because of the economic infrastructure, it can use its energy more efficiently.

The inverse relation between gross domestic product and energy consumption for Pakistan is

$$\log GDP_t = 0.3824 + 0.8080 \log E_t \quad \ldots \quad \ldots \quad \ldots \quad (1.2)$$

$$\text{St.error} = (0.0774)$$
$$t\text{-ratio} = (46.42)$$
$$R^2 = 0.992 \qquad \bar{R}^2 = 0.991$$

where GDP stands for Gross Domestic Product, E stands for commercial energy consumption and t stands for time period.

The estimated parameter has the right sign and is statistically significant. It explains about 81 percent of the variation in the dependent variable, GDP. The estimated parameter represents the commercial energy elasticity of GDP, which states that if, *ceteris paribus*, energy consumption increases by 1 percent then Pakistan's GDP will increase by 0.8 percent. This result, however, must be interpreted with caution, because the productive system uses many factors of production – capital, labour, raw materials and energy. All these factors, through a production process, are transformed into an annual flow of goods and services. Thus the partial contribution of each factor to the economic growth must be assessed simultaneously. This calls for an estimate of an aggregate production function with special emphasis on energy input. Because of limited data availability it was only possible to estimate such a function for the manufacturing sector of the Pakistan economy.[4]

From the above discussion it seems that there is sufficient evidence to support the thesis that economic growth and energy consumption are closely related and the economic development process is highly energy-intensive. Thus a basic inference may be drawn that social and economic structure of an economy could be substantially and regressively altered by large constraints upon energy use. An extreme version of this argument will imply that energy savings in the developing countries cannot be achieved unless GNP is proportionately reduced *pari passu* with energy consumption. Thus living standards as measured by levels of employment, health, education and other ameneties can only be improved by increasing employment and productivity, which are closely related to the energy consumption. Therefore, the energy supplies in developing countries must avoid constraints, which can be caused by controlled prices, delayed development of feasible technical options or shortage of foreign exchange etc. Hence, there is a need to estimate future energy demand (which is consistent with the societal progress targets of the country) and to plan for adequate supplies.

A number of energy forecasts[5] have been based on the relationship between the energy consumption and the gross national product (or energy/output ratio) such as given in equation (1.1). While such empirical findings and their interpretation are interesting and stimulating, I, however, feel these are of limited value in forecasting or for measuring the impact of energy shortages.[6] Hence, there is a need for a more refined approach to the energy projections.

ENERGY PROJECTIONS FOR PAKISTAN

The energy demand behaviour is reflected in two-fold sequential decisions. First, in the purchase of a specific fuel-burning durable consumer good and, second,

[4]For such estimates, see Riaz [13]. The results show increasing return to scale.

[5]See, for instance, Starr and Field [14], who have adopted the following approach. First they forecast employment levels using population forecasts. Then using forecasted employment they forecast future GNP and then using it in energy/GNP empirical relationships they have forecasted the energy requirement for a specified future.

[6]These aggregate empirical relationships are of limited value as there is no stable 'world line' to forecast energy consumption over time. Each country's energy demand is determined by climate, orientation of the economy, efficiency of industrial and household conversions, energy prices and the share of non-productive energy uses. Thus, the forecasts based on the aggregate analysis cannot be more than just rough estimates. However, rough estimates are of little value, because overestimation can lead to overcapacity and underestimation may bring shortages. Overcapacity is wasteful in a capital-deficient country and energy shortages can constrain economic growth.

in the frequency and intensity of its use. The stock of fuel-burning durable goods is fixed in the short run, but it is a variable in the long run. To take account of these features and economic reality, a combination of behavioural and fixed coefficients type models have been developed to make energy projections for Pakistan.

The adapted model is a partial adjustment type which takes account of the consumer's habit formation and the vital role of fuel-burning durable goods.

$$Y_t^* = \alpha + \beta X_{it} + U_t \quad (i = 1,2,3,\dots N \quad \dots \quad \dots \quad \dots \quad (2.1)$$

$$Y_t - Y_{t-1} = \lambda (Y_t^* - Y_{t-1}) + U_t \quad \dots \quad \dots \quad \dots \quad (2.2)$$

where Y_t^* is the ideal (or desired) but unobserved level of the dependent variable (i.e. fuel demand) at time t; X_{it} are the independent variables e.g. own price, income/output, cross prices) which determine the level of each fuel demand; Y_t is the actual observed level of the dependent variable (i.e. fuel consumption) at time t; and λ is an adjustment coefficient which indicates the rate of adjustment of Y_t to Y_t^* and its value lies between zero and 1.

The value of Y_t^* in (2.1) is not known but it is assumed that the consumer wishes to move from Y_t to Y_t^*. However, he is only partially successful during one time period. The reasons why Y_t does not adjust to Y_t^* in one period are many and may include economic, technological and institutional constraints as well as habit formation.[7] The relation (2.2) provides a link between Y_t and Y_t^*. Determining λY_t^* shows that

$$\lambda Y_t^* = Y_t + (\lambda - 1) Y_{t-1} - U_t = \lambda(\alpha + \beta X_{it} + U_t) \quad \dots \quad \dots \quad \dots \quad (2.3)$$

Substituting Y_t^* in (2.3) gives

$$Y_t = \alpha\lambda + \beta\lambda X_{it} + (1-\lambda) Y_{t-1} + e_t \quad \dots \quad \dots \quad \dots \quad (2.4)$$

where

$$e_t = \lambda U_t + U_t$$

Following the above, the following set of demand equations is obtained:

$$Y_{ijt} = F(P_{ijt}, X_{kjt}, Y_{ijt-1}) \quad \dots \quad \dots \quad \dots \quad (2.5)$$

[7]For a good discussion on habit formation, see Griliches [4] and also Balestra [1] which discusses it in the context of the demand for fuels.

where Y_{ijt} stands for the quantity demanded of fuel i (i = electricity, gas, oil and coal) in sector j (j = agricultural, industrial and domestic/commercial) in time period t; P_{ijt} stands as unit-price of fuel l in sector j in time period t; X_{kjt} stands for independent variables K (K = income/output, number of customers) in sector j in time period t; and Y_{t-1} is one year lagged demand.

The transport sector's and the power industry's demand for fuels has been estimated separately, using an input-output type framework. The transport sector's demand for petroleum products is based on the number of vehicles and estimated fuel consumption per vehicle per year.[8]

The power industry's demand for fuels has been estimated, using a fuel efficiency factor of different thermal plants and their annual output, which in turn has been determined by an optimal energy plan.

The non-commercial energy demand is explained by the following model.

$$NCE_t = F(Y_t, P_t, T_t) \quad \ldots \quad \ldots \quad \ldots \qquad (2.6)$$

where NCE stands for per head non-commercial energy consumption; Y stands for per head real income; P stands for per unit real prices of commercial energy; and T stands for time-related social and economic progress. The subscript t indicates time period in years.

The set of demand equations (2.5) in log linear form have been estimated using the generalized-least-squares method and 20 annual observations. The prices

[8]The transport sector does not consume any natural gas and the consumption of coal and electricity is strictly confined to railways. The railways demand for coal and electricity and the aviation demand for petroleum products are based on a simple trend. The rest of demand estimates were arrived at by developing a difference equation, such as: $X_t = f(X_t, DX_t, AX_t)$ where D is drop-out rate and A stands for new vehicles to develop time-series data for buses, tractors, cars and light vehicles, and then using the following fuel consumption figures:

HSD	Consumption/Tractor/Year	=	18.83 tons
HSD	Consumption/Bus/Year	=	10.69 tons
MS	Consumption/Car/Year	=	1.237 tons
MS	Consumption/2 & 3 wheels/Year	=	0.412 tons

These estimates are given by the Pakistan Planning Commission [9].

used as explanatory variables are the real (i.e. deflated) average prices. Income or output variable has also been deflated. The estimates[9] which are presented in Tables 1–5 have been obtained from the transformed equations based on the generalized difference process. The sources of data are shown in Appendix 2 Table 1.

The estimates, in most cases, are economically and statistically significant and provide a reasonable explanation of energy demand in Pakistan.

As at the root of all energy projections lies a judgement on the probable level of output of goods and services of a future economy, which is a quantitative corollary of a perceived future level of economic welfare and development, the future perception of economic growth, which is also realistic, must be based on the historical growth rates of employment, productivity and output. Thus, in developing energy projections for Pakistan it is assumed that Pakistan must achieve a growth rate which is equal to historical growth rate and which is possible to achieve with continuous advances in the growth of productivity, employment and output. The changes in GNP and sectoral output have been obtained by establishing time-path predictions to 2005.[10] The population forecast is taken from the Pakistan census series. The number of customers is based on planned targets. The energy prices are assumed to move up to their international levels and then maintain their values in real term. The energy projections based on the estimated models and the future perceptions as outlined above are shown in Appendix 2 Table 2.

The projections show an average growth rate of 5.5 percent over the planning horizon. The consumption of commercial fuels will increase (7.0 percent) at a greater rate compared with non-commercial energy (1.98 percent). This reflects the energy-intensive nature of industrialization, urbanization and substitution of commercial for non-commercial fuels. However, it must be pointed out that in spite of this rapid increase in energy consumption the per capita energy consumption in Pakistan in the year 2005 will still be about 18.26 GJ which is fairly close to the subsistence-level energy consumption of 10.432 GJ.

[9]A number of statistical problems faced in estimation or prior to the estimation were resolved as such. The problem of joint determination of dependent and independent variables was easy to resolve as energy prices in Pakistan are set by public regulation rather than by market forces. Furthermore refuge is taken under the partial equilibrium blanket, accepting the view that a vast system of simultaneous equations has its place in economic theory, but it may not contribute much to the cause of empirical research. The problem of identification is serious especially in the presence of cross-price variables. For such a model there exists no valid criterion to test identification. The structural parameters of our model, however, satisfy ordinary statistical tests. The problem of perfect collinearity was not faced as the matrix of the independent variables (i.e. XX) was found to be non-singular. The generalized-least-squares method has been used to deal with the milder form of multicollinearity and auto-correlation.

[10]The trend growth rates are GNP = 6.3%; industrial output = 7.5%; agricultural output = 2.9% and population = 2.5 to 2.9%.

Table 1

Estimated Demand Models for Electricity

Explanatory Variables	Class of Customers: Residential/ Commercial		Industry		Agriculture	
1. Price of Electricity	−0.117	(0.042)	−0.092	(0.023)	−0.088	(0.031)
2. Price of Natural Gas	NS		−0.017	(0.006)	NU	
3. Price of Oil	0.021	(0.012)	NS		0.032	(0.012)
4. Price of Coal	NS		NS		NU	
5. Real Income per capita	0.416	(0.151)	–		–	
6. Real GDP (Sectoral)	–		0.598	(0.128)	0.403	(0.065)
7. Quantity Demanded in Previous Year	0.718	(0.235)	0.614	(0.301)	0.632	(0.213)
8. Number of Customers	0.250	(0.109)	0.301	(0.068)	0.178	(0.055)
$\bar{R}^2$	0.95		0.976		0.985	
DW	2.15		1.95		1.89	
$\dot{P}$	0.165		0.210		0.269	

Notes: All prices are Rupees per giga-joule (Rs/GJ). All money units are deflated. The number of customers (i.e. variable No. 8) is not transformed to natural logarithmic.
NS stands for statistically non-significant at 5-percent level, hence dropped from estimation.
NU stands for 'not used' in this sector. The figures in parentheses are standard errors.
$\bar{R}^2$ stands for adjusted correlation coefficient.
DW stands for Durbin Watson test.
$\dot{P}$ is estimated Hildreth Lu coefficient.

Table 2

*Estimated Demand Models for Oil**

Explanatory Variables	Class of Customers: Residential/ Commercial		Industry		Agriculture	
1. Price of Electricity	NS		NS		NS	
2. Price of Natural Gas	0.132	(0.054)	0.093	(0.015)	NU	
3. Price of Oil	−0.106	(0.033)	−0.159	(0.022)	−0.219	(0.102)
4. Price of Coal	NS		NS		NU	
5. Real Income per Capita	0.363	(0.093)	–		–	
6. Real GDP (Sectoral)	–		0.231	(0.016)	0.426	(0.205)
7. Quantity Demanded in the previous year	0.538	(0.227)	0.761	(0.320)	0.600	(0.175)
$\bar{R}^2$	0.928		0.952		0.90	
DW	2.01		2.11		1.95	
$\dot{P}$	0.28		$\dot{P}$ 0.205		0.143	

*Same notes apply to this table as in Table No. 1.

Table 3

*Estimated Demand Models for Natural Gas**

Explanatory Variables	Class of Customers: Residential/ Commercial		Industry		Agriculture
1. Price of Electricity	NS		NS		No Natural Gas is used in this sector.
2. Price of Natural Gas	−0.115	(0.014)	−0.113	(0.036)	
3. Price of Oil	0.047	(0.020)	0.102	(0.42)	
4. Price of Coal	NS		NS		
5. Real per Capita Income	0.891	(0.216)	–		
6. Real GDP (Sectoral)	–		0.673	(0.227)	
7. Quantity Demanded in the Previous Year	0.369	(0.107)	0.481	(0.116)	
8. Number of Customers	0.179	(0.058)	0.217	(0.075)	
$\bar{R}^2$	0.962		0.988		
DW	2.14		1.98		
$\dot{P}$	0.12		0.192		

*The same notes apply to this table as in Table 1.

Table 4

*Estimated Demand Models for Coal**

Explanatory Variables	Class of Customers: Residential/ Commercial		Industry		Agriculture
1. Price of Electricity	NS		NS		Coal is not used in this sector.
2. Price of Natural Gas	NS		NS		
3. Price of Oil	0.013	(0.002)	0.152	(0.084)	
4. Price of Coal	−0.103	(0.049)	−0.120	(0.041)	
5. Real Income per Capita	−0.029	(0.012)	–		
6. Real GDP (Sectoral)	–		0.340	(0.161)	
7. Quantity Demanded in the Previous Year	0.519	(0.269)	0.212	(0.069)	
$\bar{R}^2$	0.886		0.952		
DW	2.13		1.98		
$\dot{P}$	0.091		0.105		

*Same notes apply here as in Table 1.

Table 5

Estimated Demand Model for Non-commercial Energy

Explanatory Variable	Coefficients	
1. Constant	2.105	(1982)
2. Real Income per Capita	−0.104	(0.048)
3. Real Average Price of Energy (Rs/GJ)	0.092	(0.020)
4. Time	−0.047	(0.058)
R^2	0.945	
$\bar{R}^2$	0.938	
DW	1.25	

The tracking performance of the model has been checked by calculating the mean percentage errors of the dependent variables. It is found to fall between the range of 0.47 to 3.01. These magnitudes reflect that the overall performance of the model is not unreasonable. However, it must be noted that the developed projections are conditional and are subject to such uncertainties as the nature of random error, the accuracy of estimated coefficients and forecasted independent variables, etc.

ENERGY SECTOR PLAN

Once the national energy targets have been set consistent with historical growth rates and future national aspirations, a national energy plan must be developed to satisfy these energy targets. Such a plan must relate to the rest of the economy, so that the role of energy both as a driving force and as a constraint in the economic development process may be analysed.

The development of an integrated energy-economy model was found to be too ambitious because of its costs and the impossibility of data collection. In consequence, a partial equilibrium model for the Pakistan energy sector was developed and linked to an existing model of Pakistan's economy.[11] While this approach may appear cruder, it does reflect the decentralized nature of economic reality both in the analysis and in decision-making. The energy-economy interdependence has been established as such. The energy model has been developed by accepting shadow prices of economic resources (viz. capital, labour, foreign exchange, etc.) and other relevant macro variables from the global macro model. The shadow prices of manpower and foreign exchange have been used in estimating the costs of energy options. These costs, of course, exclude transfer payments. The shadow price of capital has

[11]This is a multi-sector, dynamic model of the Pakistani economy. It was developed by A. MacEwan [6]. The same model has been revised and updated by the author. See Riaz [12].

been used as a discount factor. The GNP/GDP growth rates have been used in generating demand projections for each fuel. The basic solution of the energy plan has been obtained with this information incorporated. Then, 'potential savings' resulting from the efficient decisions in the energy sector was incorporated into the input-output coefficients of the macro model and it was resolved and results observed. In concluding, it must be accepted that the linkage approach developed has been able to establish only downward linkage successfully. This means that there remains the possibility of social welfare loss.

The energy model developed is a generalized linear programming transport model of the Koopmans-Hitchcock-Kantorovich form and can be written mathematically as[12]

$$\text{Min } C^T X \quad \ldots \quad \ldots \quad \ldots \quad (3.1)$$

$$\text{sub to } A\ \underline{X} \geqslant \underline{b} \quad \ldots \quad \ldots \quad \ldots \quad (3.2)$$

$$\underline{X} \geqslant 0 \quad \ldots \quad \ldots \quad \ldots \quad (3.3)$$

where $\underline{C}$ is a cost vector, A is a 'constraint' matrix, $\underline{b}$ is a 'constraint' vector, and $\underline{X}$ is a vector of energy capacity and flows which is to be solved.

The model finds a set of capacities, outputs and trade levels (i.e. $\underline{X}$) through the energy system (i.e. A) that minimizes the total costs (i.e. $\underline{C}$) of energy supplies over time to the nation subject to the constraints (i.e. $\underline{b}$) of satisfying specified energy targets, capacity, resources and trade limitations. The optimization has been performed by minimizing the present value of total costs over the entire planning period.

The basic optimal plan based on economic costs and other relevant data is presented in Tables 6 and 7. The data used are given in Appendix 1, Table 3.

The optimal plan favours the development of biogas, coal, gas, oil and electricity (hydro and gas-based) capacity. This reflects their comparative advantages. The synthetic oil/gas industries have not been chosen because of their relative comparative costs. The base load demand for electricity is shared between hydro, nuclear and gas/steam plants. The medium load demand is satisfied by gas and coal plants whereas the peak load is met by operating oil, coal and gas turbine plants. The trade pattern of optimal solution also reflects the relative availability of fossil fuels in Pakistan.

[12]The model consists of an objective function (viz. minimization of total costs) and seven sets of constraints (viz. demand-supply, capacity, firewood situation, import-export limits, maximum resources, maximum capacity, and finally seasonal hydro constraints). It took 0.11 minutes of IBM 370 machine to find an optimal solution. The full algebraic detail of the model are given in Riaz [11].

Table 6

Basic Solution: Capacity, Output and Energy Trade (MGJ)

	Planning Periods				
	1981–85	1986–90	1991–95	1996–2000	2001–2005
New Capacity					
1. Biogas Plants	431.444	51.00	12.00	12.00	13.00
2. New Forests	0.0	0.0	0.0	0.0	0.0
3. Coal	28.917	19.283	5.174	9.262	25.815
4. Oil	325.567	0.0	0.0	0.0	0.0
5. Gas	59.795	54.729	144.112	1039.882	674.652
6. Synthetic Gas	0	0	0	0	0
7. Synthetic Oil	0	0	0	0	0
8. Coal Power	0	0	0	0	0
9. Oil Power	0	0	0	0	0
10. Gas Steam Power	0	70.605	114.668	691.360	363.267
11. Gas Turbine Power	161.559	0.0	0.0	0.0	0.0
12. Hydro R.O.R.	10.270	0.0	0.0	0.0	0.0
13. Hydro Storage	214.009	65.078	86.913	0.0	0.0
14. Nuclear Con.	0.0	0.0	0.0	0.0	161.236
15. Breeder	0.0	0.0	0.0	0.0	0.0
16. Solar	0.0	0.0	0.0	0.0	0.0
Trade					
1. Coal Imports	0.0	0.0	0.0	0.0	0.0
2. Oil Imports	0.0	1358.704	1593.905	1869.511	2189.885
3. Oil Exports	379.325	0.0	0.0	0.0	0.0
4. Gas Imports	0.0	0.0	0.0	0.0	0.0
5. Gas Exports	132.624	181.552	246.402	714.349	982.704
Output					
1. Biogas	1941.500	2196.32	2436.809	2659.239	2862.199
2. Firewood	0.0	0.0	0.0	0.0	0.0
3. Coal	326.642	413.417	436.698	478.378	528.953
4. Oil	1531.660	0.0	0.0	0.0	0.0
5. Gas	1326.236	1815.521	2464.024	7143.492	9827.047
6. Synthetic Gas	0.0	0.0	0.0	0.0	0.0
7. Synthetic Oil	0.0	0.0	0.0	0.0	0.0

Table 7

Basic Solution: Optimum Output Schedules for Power Plants (MGJ)

Years & Load Level / Plants	1981–1985			1986–1990			1991–1995			1996–2000			2001–2005		
	Base Load	Medium	Peak	Base	Mudium	Peak	Base	Medium	Peak	Base	Medium	Peak	Base	Medium	Peak
Lignite Plants			0.027			0.474			0.474		3.169			2.982	
Oil Plants			0.117			0.117			0.117			0.117			0.059
Gas Steam		14.154			41.968		14.373	84.945		964.716	212.156		1236.387	309.06	
Gas Turbine		59.248	2.057		59.358	2.449		52.172	3.523		27.739	7.175		8.649	9.562
Hydro run	32.564			32.564			32.564			32.564			29.860		
Hydro	613.844			864.322			1170.995			1170.995			1150.466		
Nuclear Con.	12.005			12.005			12.005			12.005			459.882		
Breader															
Solar															

The total cost of the plan amounts to Rs. 336.75 billion, whereas the capital costs amount to Rs. 172.4 billion and the total foreign exchange needs are about Rs. 182.74 billion. The capital and foreign exchange requirements stated in annual terms show that the energy sector will require Rs. 6.9 billion in the form of capital funds and Rs. 7.31 billion in the form of foreign exchange. The Pakistan energy problem thus turns out to be not a problem of resources or technology but of foreign exchange availability. The financial and foreign exchange requirements of the Pakistan energy sector along with the power intermediate demand for fuels is listed in Appendix 2 Table 4. The intermediate demand is forecasted by an annual growth rate of 11.4 percent. The major part of this demand will be satisfied by natural gas.

If the implementation of the energy sector plan (which is consistent with economic growth and the shadow prices of economic resources) did not affect economic scarcities elsewhere in the economy, then the optimal solution is a part of a general equilibrium which ensures maximization of social welfare. However, in view of the large capital and foreign exchange requirements, the economic scarcities are quite likely to be affected. In order to take account of this possibility, the energy model has been solved[13] using different sets of shadow prices of the basic economic resources (viz. capital and foreign exchange). Then the percentage difference between the most expensive and the least expensive plan has been calculated. Then this difference is assumed to represent 'a potential saving' resulting from a better choice of energy options.

The cost differences (or potential savings) turn out to be 35 percent between the most and least expensive plans. This can be seen in the Table 8 which shows the total discounted costs of six alternative optimal plans.

The potential savings of 35 percent was then incorporated as an increased efficiency in the input-output coefficients of the energy industries in the macro model. With this efficiency (i.e. 35 percent) incorporated, the macro model optimization was repeated. (This is exactly what would have happened if the model was an energy-economy integrated model.) The new optimal solution did not show any major changes, except that the changes in shadow prices are less than 5 percent and the value of the maximand (i.e. national consumption) is changed less than 2.1 percent and the effects on production levels are of similar order of magnitude. These relatively minor changes in the shadow prices and national income can be explained

[13]The changes in the structure of the optimal solution resulting from the changes in the shadow prices of capital and foreign exchange are discussed in Riaz [13]. The capital and foreign exchange prices were allowed to vary up to 100% of the level used in the basic model.

Table 8

Total Discounted Costs of Six Alternative Plans
(Rs. billions)

	A	B	C	D	E	F
Total Discounted Costs	336.75	328.3	300.4	402.3	297.6	315.6

Note: Plan A shows the cost of basic solution; Plan B shows total costs based on commercial prices; Plan C shows costs based on $ = 15.63 Pak. Rs. and r = 12.5%; Plan D shows costs based on $ = 25.0 Pak. Rs. and r = 12.5%; Plan E costs are based on $ = 15.63 Pak. Rs. and r = 20% and Plan F costs are based on $ = 25.0 Pak. Rs. and r = 20%.

by the large labour earnings from the Middle East, which have led to an increase in national income, capital and foreign exchange availability.

Since 1950, Pakistan's GNP has grown by an average growth rate of 5 percent, which has led to an increase in personal per capita income and personal consumption. This increased real income and consumption is the result of greater industrialization and economic productivity, which are directly associated with the expanded energy use throughout the economy. If continuity of this trend is desirable as a national objective and one wishes to avoid energy constraints on social and economic progress, then Pakistan should adopt energy targets as specified in section 2 of this paper; and to achieve these targets, the energy plan of this section must be implemented, which favours the development of domestic resources of coal, natural gas, oil and hydro and nuclear electricity. It also favours the development of the biogas industry. Since new energy supply options have historically taken 30 to 50 years to become significant we cannot count on solar or breeder reactors. However, continuous diligent efforts in research, development, engineering and system integration should be pursued to assure availability to the future generation.

The two-way linkage approach between the energy sector and the rest of the economy, as developed in this section is not completely satisfactory because of different methodologies and aggregation levels employed in the two levels. Therefore, in Appendix 1 an alternative approach has been adopted to assess the impact of energy-economy interaction on the level of income and energy prices, and demand.

Appendix 1

ENERGY-ECONOMY INTERACTION: AN ALTERNATIVE APPROACH

As of 1980 the value of Primary energy inputs in Pakistan has not exceeded 6 percent of GNP.[14] The net oil import bill in 1980, stood at Rs. 8.921 billion, which is 16.36 percent of total imports and 30 percent of total exports in the same year. However, it is also important to note that the net oil import bill of 1980 is only 49 percent of the labour remittances from the middle east, which are a direct consequence of the increase in oil prices since 1973. The energy sector investment in Pakistan, has been less than 15 percent of capital formation.

The above given statistics are suggestive, but not conclusive in themselves in determining the significance of the energy sector in relation to the rest of the economy. Hogan and Manne have developed a simple single output, two inputs (i.e. energy and non-energy) model[15] to show the possible impact of energy-economy interactions. Using a price/marginal productivity relationship the authors show the importance of energy sector in the national economy as such:

$$(\Delta F/\Delta E)\cdot(E/Y) = (Pe\cdot E)/Y \quad \ldots \quad \ldots \quad (4.1)$$

where the left-hand side of (4.1) describes the energy elasticity of output with other factors input being assumed constant. The right-hand side of (4.1) shows the value share of energy input as a proportion of total output. The implication of (4.1) is that if energy consumption changes by 1 percent it leads to n percent ($n = Pe{\cdot}E/Y$) change in GNP. If one assumes to remain constant over a wide range of E then,

$$(Y/Y_0) = (E/E_0)^n \quad \ldots \quad \ldots \quad \ldots \quad (4.2)$$

[14]In 1980, the value of primary inputs was Rs. 11.653 billion, which is 5.05% of GNP.

[15]The model is based on two accounting identities and one production function of the from

$$Y = Pe\cdot E + Px\cdot X \quad (1)$$
$$Y = Pe\cdot E + GNP \quad (2)$$
$$Y = F(E\cdot X) \quad (3)$$

The national output is maximized (i.e. 3) subject to factors availability as such.

$$Max\ F(E, X) - Pe\cdot E - Px\cdot X \quad (4)$$

where P denotes price, E stands for energy and X for non-energy. Y is non-energy sector output. See Hogan and Manne [5] for details.

where

Y stands for GNP and zero subscript indicates base-year values.

The application of (4.2) allows to make some inference about the possible impact of energy shortages on the level of GNP.

In 1979-80, the value of energy input share as a proportion of Pakistan's GNP (i.e. $n = Pe{\cdot}E/Y$) was equal to 0.055. This means that a 50 percent reduction in energy consumption would lead to mere 3.9 percent fall in GNP.

The assumption of constant n (i.e. $n = Pe{\cdot}E/Y$) is a strong and can only be justified if the price elasticity (or substitution) is equal to one, which of course is not very likely to happen. Therefore, if we assume that n is not a constant and it is likely that it may increase to 0.1 because of rise in oil and other energy prices. In that case, a 50 percent reduction in the energy consumption can lead to a fall of 6.7 percent in GNP. This 10 percent energy sector share can be considered as an upper limit in view of falling energy prices in recent years.

Having made some rough estimates to the possible impact of energy shortages on the level of GNP, what is left is to estimate the possible impact of high energy prices on energy demand over time.

The long-run price elasticities of demand for commercial fuels can be derived from Tables 1–5 and are shown below:

The long-run price elasticities of demand for commercial fuels for different sectors of the economy range from 0.152 to 0.663. However, there are only two values which are higher than 0.5, the rest of the values are fairly small. The estimated demand function for commercial energy in Pakistan is:

$$\log E_t = 0.875 + 0.661 \log GNP_t - 0.206 \log P_t + 0.270 \log E_{t-1} \quad (4.3)$$

$$\text{St. error} \quad (0.123) \quad (0.101) \quad (0.092)$$

$$R^2 = 0.97 \quad \bar{R}^2 = 0.965 \quad DW = 2.125$$

It gives a long-run price elasticity of 0.28. With this price elasticity, the possible price increase of 35 percent (This is the possible difference between the most expensive and the least expensive energy plan), can lead to a fall of 9.8 percent in the energy demand. But if we assume that the long-run price elasticity is equal to 0.5, in that case a 35 percent price increase can lead to a reduction in demand of about 17 percent. The demand variations of this magnitude are well within the forecasting errors.

In conclusion, it is evident that the balance of payment difficulties created by the high oil import bill have been compensated by the opening up of the middle eastern markets to the Pakistani goods and labour. With these opportunities Pakistan is perfectly capable to avoid any energy constraints and thus maintain her historical growth rate, which is essential for social and economic progress.

Appendix 2

Table 1

Sources of the Statistical Data

Variables	Class of Customers		
	Domestic	Industrial	Agriculture
1. Quantity demanded of each fuel	A	A	A
2. Price of Electricity	B	B	B
3. Price of Gas	C	C	C
4. Price of Oil	C	C	C
5. Price of Coal	D	D	D
6. Price: Income and Output Deflators	E	E	E
7. GNP : GDP	f	f	f
8. Population	g	g	g
9. Number of Electricity Customers	h	h	h
10. Number of Gas Customers	k	k	k

Notes:

A = "Energy Year Book" 1979-80 — Ministry of Petroleum and Natural Resources, Government of Pakistan, Islamabad.

B = "WAPDA Financial Statistics", Various Issues — Water and Power Development Authority, Government of Pakistan.

C = "Pakistan Oil and Gas Pricing" 1980 — Ministry of Petroleum and Natural Resources, Government of Pakistan.

D = "Coal Mining Industry in the Energy Perspective of Pakistan" — A. A. Malik and K. A. Siddique PMDC, Pakistan.

and

B,C,D = "Energy Data Book" — Ministry of Petroleum and Natural Resources, Government of Pakistan.

E,f,g = "Pakistan Economic Survey 1980-81" — Finance Division, Government of Pakistan.

h = "A Handbook of Data on WAPDA" — Water and Power Development Authority, Government of Pakistan.

k = Pakistan Statistical Year Book, Various Issues. — Government of Pakistan.

Appendix 2

Table 2

Energy Projections (MGJ)

Fuels \ Year	1980	1985	1990	1995	2000	2005
1. Electricity	108.13	151.76	206.11	277.41	369.30	484.76
2. Natural Gas	120.34	183.09	244.06	335.33	482.31	751.99
3. Oil	189.56	225.63	265.50	310.34	365.04	427.09
4. Coal	44.38	73.27	77.14	81.72	90.76	98.31
5. Total (1+2+3+4)	461.41	633.75	792.81	1004.80	1307.41	1762.15
6. Power Demand for Coal	0.018	0.018	0.318	0.318	2.135	5.993
7. Power Demand for Oil	0.060	0.060	0.077	0.078	0.077	0.077
8. Power Demand for Natural Gas	54.620	70.650	89.510	121.250	811.65	1038.20
9. Total Power* Industry (6+7+8)	54.620	70.728	89.905	121.646	813.862	1044.27
10. Total Commercial Energy (5+9)	516.108	704.478	882.715	1126.446	2121.272	2806.42
11. Total Non-Commercial Energy	359.36	408.29	459.45	505.29	549.18	586.97
12. Total Energy (10+11)	875.468	1112.768	1342.165	1631.736	2670.45	3393.39

*Power Industry Projections are Based on Table 3.4 of the paper read at the PSDE conference.

Table 3

Data Used in the Computation of the Model

Fuels and Plants (J)	Costs[a] (Rs.) CC/GJ	VC/GJ	TC/GJ	Existing Capacities (Million GJ)	Reserves[b] (Million GJ)	Availability factor	Efficiency factor
Non-Commercial Fuels							
Biogas	32.55	1.95		44.34	630/year	0.9	
Firewood	27.94	3.73			37/year	0.9	
Cylinder Gas	25.11	7.10					
Kerosene	18.01	6.22					
Coal						1.03	
Coal Extraction	20.01	11.36			11.293		
Coal Import			48.30			0.9	
Coal Export			41.05				
Oil				14.80	1.780		
Oil Extraction	21.18	7.22				0.9	
Oil Manufacturing	111.36	13.34				0.8	0.70
Oil Import			61.05				
Oil Export			51.84				
Natural Gas				174.9	24.559		
Gas Extractions	18.08	7.22				0.9	
Gas Manufacturing	111.36	13.34				0.8	0.70
Gas Import			61.05				
Gas export			51.89				
Electricity							
Coal-fired Plants	311.60	37.22		0.473		0.65	0.30
Oil-fired Plants	299.60	35.54		1.987		0.65	0.30
Gas Steam Plants	281.00	33.32		35.930		0.65	0.30
Gas Turbine Plants	269.40	30.54		23.785		0.65	0.20
Hydro Run-of-river	270.80	31.10		3.407		0.60	
Hydro Storage	348.60	38.88		23.974	376.27/ year	0.65	
Nuclear Conventional	600.60	44.44		4.322		0.70	0.38
Nuclear Breeder	813.00	44.44		0.0		0.70	0.38
Solar Cell Power Plants	120.52	10.32		0.0	24.750/ day	0.65	0.10
Diesel Power Genetation	42.56	12.18		0.0		0.80	0.12

Continued –

Table 3 – *Continued*

Source : Most of the above data have been taken from official sources but some has come from the open literature especially that which is related to new technologies, i.e. synthetic oil/gas: solar cells, breeder reactors, etc. For source, see [10]. The loss factor is taken as 0.09 for all non-electric plants and 0.2 for the electric plants.

Notes: [a]CC stands for capital costs, VC for variable costs and TC for trade costs. All costs are at 1980 prices.
[b]Reserves mean proven deposits.

Appendix 2

Table 4

Energy Sector Financial, Foreign Exchange, and Intermediate Fuel Requirements

Requirements / Planning Periods	1981–85	1986–90	1991–95	1996–2000	2001–2005
a. *Finance* (bn. Pak. Rs.)					
i. Operational Costs	40.39	24.86	18.18	19.01	14.15
ii. Capital Costs	112.26	18.06	13.98	23.59	3.53
iii. Net Trade Costs	+19.26[1]	−30.79	−19.68	−10.34	−6.19
Total (i+ii+iii)[2]	133.39	73.71	51.84	53.94	23.87
Total Plan Costs	**336.75**				
b. *Foreign Exchange* (bn. Pak. Rs.)					
i. Capital Cost Component	64.21	11.38	8.81	15.49	2.22
ii. Imports (net)	–	34.29	22.32	14.58	9.44
Total (i+ii)	64.21	45.67	31.13	30.07	11.66
Total Plan Foreign Exchange Costs	**182.74**				
c. *Intermediate Fuel Demand*					
i. Coal (MGJ)	0.091	1.597	1.597	10.679	29.967
ii. Oil (MGJ)	0.386	0.386	0.396	0.386	0.386
iii. Natural Gas (MGJ)	353.233	447.526	606.224	4058.248	5191.030

Notes: [1]The positive net trade indicates a trade surplus where negative net trade indicates a trade deficit.
[2]Trade surplus has been deducted from the costs, whereas the trade deficit has been added to the costs.

REFERENCES

1. Balestra, P. *The Demand for Natural Gas in the United States.* Amsterdam: North-Holland Publishing Company. 1967.
2. Brookes, L. G. "More on the Output Elasticity of Energy Consumption". *Journal of Industrial Economics.* Volume 21, No. 1. 1973.
3. Cook, E. "The Flow of Energy in an Industrial Society". *Scientific American.* Volume 225, Number 3. 1971.
4. Grilliches, Z. "Distributed Lags: A Survey". *Econometrica.* Volume 35. 1967.
5. Hogan, W., and A. S. Manne. "The Economy Interaction: The Fable of the Elephant and the Rabbit". In R. S. Pindyck (ed.), *Advances in the Economics of Energy and Resources.* New Haven, Conn.: JAI Press Inc. 1979.
6. MacEwan, A. *Development Alternative in Pakistan.* Cambridge, Mass.: Harvard University Press. 1971.
7. Pakistan. Finance Division. Economic Adviser's Wing. *Pakistan Economic Survey, 1980-81.* Islamabad. 1981.
8. Pakistan. Ministry of Petroleum and Natural Resources. Directorate General of Energy Resources. *Energy Year Book.* Islamabad. (Various issues)
9. Pakistan. Planning Commission. "Proforma PC1 – Power and Fuel Projects". Islamabad.
10. Pakistan. Planning Commission. *Working Papers for the Development Perspective (1975–80).* Vols. I & II. Islamabad. 1975.
11. Riaz, T. "Energy Policy Formulation for Pakistan. An Optimization Approach". *Energy Economics.* Volume 3, Number 3. 1981.
12. Riaz, T. "A Multi-sector Dynamic Model for the Pakistan Economy". Newcastle-upon-Tyne: Newcastle Polytechnic. 1978. (Discussion Paper)
13. Riaz, T. *Pakistan. The Energy Sector.* Lahore: Ferozsons Ltd. (Forthcoming)
14. Starr, C., and S. Field "Economic Growth, Employment and Energy". *Energy Policy.* March 1979.

The Pakistan Development Review
Vol. XXIII, Nos. 2 & 3 (Summer-Autumn 1984)

Comments on "Pakistan: Energy Consumption and Economic Growth"

At the outset I should say that the paper is really a number of papers on a very interesting topic and embodies a tremendous amount of hard work. My comments will be mostly in the form of questions concerning the way the items integrated.

First, the production function for manufacturing shows increasing returns to scale and thus may be inconsistent with the assumption of perfect competition underlying the recommended pricing policy. Secondly, the estimation of derived demand functions for energy using partial-adjustment models may involve a production process based on a framework which is inconsistent with the aggregate production function. Thirdly, the partial-adjustment models do not involve clear specification of the objectives and constraints of agents in the economy. This may make us uneasy about the recommendation of marginal cost pricing which is based on profit maximization by producers and utility maximization by consumers.

The fourth question of inconsistency concerns an example of a problem raised by Lucas in his critique of macro-economic forecasting. Demand functions are estimated on the basis of one set of assumptions about expectations, yet forecasting is based on a changed set of policies. This may invalidate the use of the estimated demand responses.

The fifth question I had is concerned with general time-series problems in demand estimation. In this context, it is not enough to worry only about first-order serial correlation. Quite complicated time-series structures can arise, particularly in partial-adjustment models. Sixthly, I would just like to check that the marginal costs that come out of the linear programme are indeed the prices which were used. That seems to me to be the logic of the exercise but it was not clear to me that this had been done.

The last question which I am raising is whether the marginal cost is the right price. The recommendation in general ignores problems of raising revenue or assumes implicitly that revenue can be raised by lump-sum taxation. But governments have strong need for revenue, and Pakistan is no exception. In this case, taxing energy or pricing above marginal cost may be sensible.

The suggestions for consistency between elements in the complicated modelling exercise which Dr. Riaz has set himself may, however, be a counsel of perfection and we should be grateful to him for an intensive investigation into a difficult and important problem.

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