

AN ANALYSIS OF ENERGY DEMAND IN PAKISTAN, 1960-1981

by

Mahmood Iqbal

M.Sc.(Islamabad University), 1976

M.A.(McMaster University), 1979

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
in the Department
of
Economics

© Mahmood Iqbal 1985

SIMON FRASER UNIVERSITY

February, 1985

All rights reserved. This work may not be reproduced in whole or in part, by photocopy or other means, without permission of the author.

APPROVAL

Name: Mahmood Iqbal

Degree: Doctor of Philosophy

Title of Thesis: An Analysis of Energy Demand in Pakistan, 1960-1981

Examining Committee:

Chairman: Jock Munro

Terence M. Heaps
Senior Supervisor

Mahmood H. Khan

Dennis R. Maki

Kenji Okuda

Robert N. McRae
External Examiner
Associate Professor
Department of Economics
University of Calgary

Date Approved: 21/02/85

PARTIAL COPYRIGHT LICENSE

I hereby grant to Simon Fraser University the right to lend my thesis, project or extended essay (the title of which is shown below) to users of the Simon Fraser University Library, and to make partial or single copies only for such users or in response to a request from the library of any other university, or other educational institution, on its own behalf or for one of its users. I further agree that permission for multiple copying of this work for scholarly purposes may be granted by me or the Dean of Graduate Studies. It is understood that copying or publication of this work for financial gain shall not be allowed without my written permission.

Title of Thesis/Project/Extended Essay

An Analysis of Energy Demand in Pakistan, 1960-1981

Author:

(signature)

Mahmood Iqbal

(name)

February 21, 1985

(date)

ABSTRACT

Most of the available studies of the energy sector in under-developed countries are descriptive and geographical accounts of the supply-side of energy. However, the oil shock of 1973 created severe balance of payments problems for the oil-importing under-developed countries (OIUDCs). These problems have created the need for in depth studies of the demand-side of energy for OIUDCs.

The differences in the level of income, energy resource endowments, and degree of dependence on oil imports means that individual case studies of each country are required. Unfortunately, consistent data on end-use consumption of energy are not available for most of the OIUDCs. Pakistan is an exception, however, because detailed time series data on sector-wise consumption of commercial energy are available for the last 22 years. This data makes it possible to estimate the sectoral energy demand functions for Pakistan.

Models for the demand for energy in Pakistan are developed for the residential, industrial and transport sectors of the economy. These are similar to the models that have been developed for energy demand studies of developed countries. A model for the total energy demand is also developed. These models are then estimated for Pakistan. The models for the residential, transportation and aggregate demand are estimated by Ordinary Least Squares, or by Generalized Least Squares if the residuals are autocorrelated. Industrial demand is modeled

via a translog cost function and estimated by applying Zellner iterative method to the associated share equations.

The results obtained in this study show that growth in income will be the most important determinant of energy demand in Pakistan in the near future. The price elasticities of most of the fuels are small in value and weak in statistical significance. Thus there appears to be little possibility of encouraging energy conservation via pricing policy. Energy does appear as a substitute to labour and capital in production. The demand relationships between different types of fuels are also one of substitution. However, the extent of such substitution appears to be rather limited. The government's pricing and non-pricing policies related to the management of energy demand are also analyzed in the light of the results obtained in this study.

DEDICATION

To my father,

Who demonstrated optimal allocation of limited
resources among his nine children.

ACKNOWLEDGMENTS

I wish to thank my senior supervisor, Professor Terence M. Heaps for refining my theoretical understanding of resource economics during all stages of this work. Thanks are also due to the other members of my supervisory committee, Professor Mahmood H. Khan for his comments on the importance and working of energy policies in Pakistan, and Professor Dennis R. Maki for his help in econometric problems and estimation work. My special thanks is due to my wife whose warm companionship and assistance in proof reading, revision and typing the manuscript has made this work possible.

TABLE OF CONTENTS

Approval	ii
ABSTRACT	iii
Dedication	v
Acknowledgments	vi
List of Tables	ix
Definitions and Abbreviations	xi
INTRODUCTION	1
I. HISTORICAL BACKGROUND, DATA AND ESTIMATION	17
1. Background	17
2. Data	25
3. Estimation	28
II. DEMAND FOR ENERGY IN THE RESIDENTIAL SECTOR	33
1. Model	33
2. Regression Results	37
III. DEMAND FOR ENERGY IN THE INDUSTRIAL SECTOR	45
1. Model	47
2. Data	59
3. Results on Factor Substitution	63
4. Results on Interfuel Substitution	75
IV. DEMAND FOR ENERGY IN THE TRANSPORTATION SECTOR	81
1. Model of Gasoline Demand	83
2. Regression Results on Gasoline Demand	85
3. Model of Fuel Demand by Other Transportation Modes	89
4. Regression Results of Aviation fuel Demand	91

5. Regression Results of Fuel Demand by Other Modes ..	93
V. AGGREGATE ENERGY DEMAND	98
1. Model of Aggregate Energy Demand	99
2. Regression Results	106
3. Model of Individual Fuel Demand	109
4. Regression Results	112
VI. CONCLUSION	124
APPENDIX: POLICY ISSUES RELATED TO ENERGY DEMAND	129
1. Pricing Policies	129
2. Other Considerations	141
REFERENCES	148

LIST OF TABLES

TABLE	PAGE
I-1.	Energy Imports and External Debt in Relation to GDP, Exports and Imports, 1970 and 1978 18
I-2.	Annual Growth Rates and GDP Elasticities of Commercial Energy Consumption in DMCs 20
I-3.	Energy Balance Sheet of Pakistan, 1981 22
I-4.	Sector-wise Consumption of Commercial Energy (Billion BTUs and Percentages) 24
II-1.	Regression Results of Residential Demand for Fuel in Pakistan (1961-81) 39
II-2.	Short & Long Run Income and Price Elasticities 41
III-1.	Parameter Estimates of Factor Share Model of All Industries Pooled in Pakistan 64
III-2.	Parameter Estimates of Factor Share Model of Sets of Industries Pooled in Pakistan 67
III-3.	Elasticities of Substitution of Labour, Capital and Energy in Manufacturing Sector of Pakistan 69
III-4.	Partial Price Elasticities of Demand for Labour, Capital and Energy in Manufacturing Sector of Pakistan 71
III-5.	Parameter Estimates of Fuel Share Model in Manufacturing Sector of Pakistan 77
III-6.	Elasticities of Substitution and Partial Price Elasticities of Demand for Fuel in Manufacturing Sector of Pakistan 78
IV-1.	Regression Results of Gasoline Demand in Pakistan 87
IV-2.	Regression Results of Aviation Fuel Demand in Pakistan 92
IV-3.	Regression Results of Fuel Demand by Other Modes of Transportation in Pakistan 95

V-1.	Regression Results of Aggregate Energy Demand in Paksitan (1961-81)	107
V-2.	Regression Results of Fuel Demand in Pakistan (1961-81)	113
V-3.	Parameter Estimates of Share Equations of Aggregate Energy Demand in Pakistan	117
V-4.	Elasticities of Substitution of Aggregate Energy Demand in Pakistan	118
V-5.	Partial Own and Cross Price Elasticities of Aggregate Energy Demand in Pakistan	119

DEFINITIONS AND ABBREVIATIONS

Definitions

Agriculture Demand:

Consumption of commercial energy by tubewells and tractors.

British Thermal Unit (BTU):

The quantity of energy required to raise a pound of water one degree fahrenheit.

Commercial Energy:

This comprises those energy forms in which there is a large international and domestic market, and which supply the needs of an industrial economy, i.e. petroleum fuels, natural gas, electricity, coal and hydro.

Industrial Demand:

Consumption of commercial energy in the industrial sector excluding the cement, fertilizer and power.

Residential Demand:

Consumption of commercial energy in houses, shops, offices, banks, and other commercial buildings, i.e. all in house consumption plus street lights.

Statistical Significance:

The t-statistic with 19 degrees of freedom suggests that a parameter estimate is statistically significant at 5% significance level when its value is higher than + 1.73. The parameter estimate is statistically significant at 10% level

when its value is higher than + 1.33 [53].

Transportation Demand:

Consumption of commercial energy by commercial transport (bus, taxi, train, air and water transport) plus consumption by government and defence transport (government vehicles, air force, navy etc.) plus private consumption by motor cars etc., plus overseas consumption by foreign air lines or foreign ships.

Non-Commercial Energy:

This comprises all those fuels commonly used in the traditional sector of the economy, such as wood, charcoal, crop residuals, and animal dung. The term is somewhat misleading since these commodities often have a cash value and enter into commerce, but their procurement and availability does not depend on the application of modern technology.

Urbanization:

The proportion of rate of growth of population of urban areas to the rate of growth of population of the country.

Abbreviations

CSO is the Central Statistical Office

FO is Furnace Oil

HSD is High Speed Diesel

KESC is Karachi Electric Supply Company

LDO is Light Diesel Oil

LPG is Liquefied Petroleum Gas

MESCO is Multan Electric Supply Company

OGDC is Oil and Gas Development Corporation

PMDC is Pakistan Mineral Development Corporation

REPCO is Rawalpindi Electric Supply Company

TCO is Tons of Coal Equivalent

WAPDA is Water And Power Development Authority

INTRODUCTION

Most of the studies available of the energy sector in under developed countries (UDCs) are descriptive and geographical accounts of the supply-side of energy. The few studies on the demand-side of energy chronicle the growth in consumption of various types of energy without trying to model these within a consistent framework [36]. There are a few studies focusing on the causal relationship between the demand for energy and economic and demographic factors, i.e. income, price and population. Some of these studies are ad hoc in selecting explanatory variables for estimating energy demand. Other studies are based on sound theoretical models. However, these studies bring together all UDCs into one group and estimate the aggregate energy demand for all sectors of their economies jointly [15;16]. The former (ad hoc) analysis assumes that the presence of supply constraints and government interference in free market trading precludes the use of the neo-classical framework for energy demand modelling in UDCs. Other studies lack the end-use energy consumption data of different sectors of the economy for each UDC and therefore, so do only an aggregate analysis of energy demand.

Neo-classical demand theory can be applied in energy demand estimation if for a given price the corresponding unit of consumption represents an observation on the demand curve. At this price, demand and supply should be equated. One of the UDCs

which meets this specification is Pakistan. ¹ This is because in Pakistan, the supply of energy is generally controlled by the government. Of the total domestic supply, 60% is supplied by government agencies, 30% is managed by foreign companies and 10% is owned by private shareholders and local financial institutions [71]. The difference between demand and domestic supply is made up by imports, which are deliberately controlled by the government in order to eliminate the excess demand.

The prices of various forms of energy are also fixed by the government. The wellhead prices of oil and natural gas are determined by the government in consultation with the private oil and gas producing companies in Pakistan. The price of indigeneous oil takes into account the international prices of crude oil of similar quality prevalent in the Persian Gulf area [71]. The price of natural gas covers the costs of exploration, development and operation. Electricity tariffs are determined by KESC, WAPDA, MESCO and REPCO in accordance with the pricing arrangements prescribed by the federal government [71].

Purification, transmission and distribution charges for the natural gas companies have also been determined by the government [71]. The final sale price of petroleum products is based on five elements, which are all fixed by the government.

¹There are other reasons for selecting Pakistan as a case study. First, there is an acute lack of research on its energy sector, especially on the demand side. Second, unlike most UDCs, there are time-series data available for Pakistan on consumption of energy for the past 22 years to enable the estimation of sectoral energy demand functions.

These are: (a) the ex-refinery price, (b) excise or custom duty, (c) a petroleum development surcharge, (d) distributors margin, and (e) the inland freight margin, out of which the marketing companies receive actual transportation expenses [96].

Given fixed prices of fuels, government examines the existing demand and domestic supply of these fuels. ² During 1981, domestic sources supplied only 65% of the total demand of fuels; the gap was met by imports of oil and petroleum products [70]. These prices of fuels are not only supposed to cover the cost of production and importation if required, but more importantly meet certain social objectives. For example, kerosene is subsidized, as it is used by the masses. Gasoline, on the other hand, is taxed heavily as it is consumed by automobile owners, who are considered to be rich.

However, the system of cross-subsidies has generated imbalances in the demand for different petroleum products. The demand for the subsidized products, gasoline and light diesel oil, exceeded the demand for other refinery output, naphtha and furnace oil. As a result, Pakistan was forced to re-export the latter at substantial costs, while importing large quantities of the former at premium prices [26]. Price differentials also exist between various categories of consumers of natural gas. As a result, there has been a rapid expansion in the use of natural gas in the power, cement and fertilizer industries and the

²The demand for fuels is estimated by the planning authority on the basis of projected growth of national income.

residential sector. The current tariff structure of electricity is characterized by a variety of charges to favour low voltage customers. Thus the existing tariff is unnecessarily complex [96].

The amount of energy supplied by private companies is based on calculations of economic profit. If the price is below the opportunity cost of producing the fuel, the production of that fuel is either curtailed (if the Agreement allows) or at least, any increase in production of the fuel is postponed.³ The supply of natural gas is a good example. The government's failure to revise the wellhead price of gas in accordance with the rising costs of production resulted in private companies declining to supply the additional gas needed. As a result, supply could not keep pace with the increasing demand. For a temporary period during 1983, the government had to resort to non-price measures like shutting off the supply of gas in some localities of Karachi at different times of the day. The government now plans to revise the price of gas and this is expected to bring an encouraging response from the private producers [67].

The prices of various forms of energy, determined by the government, are expected to clear the market. In a situation where the government-regulated price fails to clear the market, non-price measures like rationing and queuing would have to be

³ According to Pakistan Petroleum (Production) Rules of 1976, the sum of royalty payments (12.5%) and other taxes on the income of oil and gas producing companies should not exceed 55% nor be less than 50% of gross profits [96].

adopted. During the last 22 years, non-price activities were not reported, except for the year 1965, when kerosene was rationed, and during 1983 when supply of natural gas was temporarily shut off as mentioned above [26;67].

This implies that given the available supply and the demand for fuels, prices of fuels have been fixed at levels that have cleared the market atleast on an annual basis. The analysis of this paper is based on yearly observations.

The role of the government in determining the quantity and price of fuels in Pakistan may be considered an impediment when applying the neo-classical demand theory for estimating energy demand. This constraint has also been observed in the United States as noted by Mause [59]:

Virtually all energy consumed in the US economy, except for coal used directly by industry, is either subject to price regulation it self or is converted into price-regulated electricity. Although the direct price regulation of petroleum is a relatively recent phenomenon, natural gas and electricity have long been subject to price regulation. At present, roughly 50% of energy consumed in the United States is sold through price-regulated natural gas and electric utilities. Most of this 50% is subject to price regulation by state utility commissions. The distribution of natural gas and the distribution of electricity appear to be natural monopolies and even if price regulation of natural gas at the wellhead is discontinued, gas pipeline and distribution utilities will continue to be regulated.

In spite of the limitations pointed out by Mause, it has been standard practice in existing studies to use the neo-classical framework to estimate energy demand. See, for example, [4;11;65;77].

Lack of energy is a bottleneck in the economic development of UDCs. The importance of commercial energy in the economic development of UDCs, especially in Pakistan is analyzed in chapter I. The variables, data and the methodological issues related with the estimation work are also discussed in chapter I.

Pakistan is basically an agrarian country. The agricultural sector provides employment to 70% of the population and contributes 31% to GNP. [66].⁴ The process of mechanization is necessary to boost productivity in the agricultural sector. This requires an intensive use of tractors, fertilizers, pesticides etc., all of which need energy as an input.

The industrial sector in Pakistan has partially completed the primary and intermediate phases of import substitution in certain fields. It is now attempting to become self-sufficient in heavy industries [72]. This will generate a tremendous demand for energy.

The transportation of commodities such as grains, cement etc. is dependent on diesel vehicles requiring middle distillates as fuels. Passenger traffic is expected to increase with rising income and the level of urbanization. This will put additional upward pressure on the demand for petroleum products.

Although Pakistan imports 35% of its energy needs, these imports constitute 90% of the total requirements of oil and petroleum products and cost 54% of the country's export earnings

⁴ All figures used in this chapter are for the year 1981.

[38]. This is a precarious situation. Remittances by Pakistani workers in the Middle East have allowed Pakistan to pay for about half of the oil bill, but these remittances may not continue in the future. The more serious side of the dependence of Pakistan on imported oil is perhaps the periodic uncertainty about OPEC oil pricing policies and political instability in the Middle East in general.

An in depth study of energy demand is, therefore, important for analyzing the pattern of energy consumption and exploring the possibility of energy conservation in Pakistan. Such a study would help with the estimation of future needs for different types of fuels. It would assist in determining optimal pricing policies which would minimize the gap between the demand and the domestic supply of fuels. It would also help in analyzing the macroeconomic impacts of a sudden increase in the prices of imported fuels and enable steps to be identified which could help the economy to absorb these shocks.

In the context of energy demand, the critical questions to be investigated are as follows: (1) What is the income elasticity of the demand for energy? (2) What is the price elasticity, especially given the dramatic increase in the price of energy relative to other goods? (3) What is the time distribution of the response to the price increases of 1970s? (4) What are the elasticities of substitution between energy and non-energy inputs and between different forms of energy? (5) Finally, how far are these elasticities different from the

elasticity estimates for the developed countries?

The uses of energy can be explained on a sector-by-sector basis as well as on the basis of an aggregate analysis. The determinants of energy demand for home heating would be very different from that of industrial production. Thus the characteristics of energy demand for each sector need to be examined separately. However, aggregate energy demand analysis is important because it provides simple summary parameters. It is useful for the projection of total energy demand of the country, because it avoids the cumulation of errors resulting from the projection of demand for individual fuels or individual sectors.

In this study, sectoral energy demand will be analyzed for the residential, industrial and transportation sectors. These account for about 90% of the total commercial energy consumed in the country [70]. Although the agricultural sector contributes 31% to the GNP, it relies heavily on non-commercial sources for its energy requirements.⁵ The agricultural sector is included in the analysis of total commercial energy demand.

A major portion of natural gas supply is also required for transformation into electricity and as a feedstock for the production of fertilizer [72]. The estimates of aggregate energy demand take into account all commercial energy consumed in the

⁵The agricultural sector consumes about 8% of total commercial energy [70].

economy.⁶

The residential sector consumes about 16% of the total supply of commercial energy [70]. The model for the residential demand for fuel has been developed from considerations of the stock of fuel-consuming appliances and their rate of utilization. The rate of utilization is assumed to be a function of income, relative prices of fuels and temperature. The need for data on the stock of appliances has been eliminated by assuming that the consumer is in a process of continuous partial adjustment towards a desired stock of appliance holdings. The desired holding depends on income, relative prices of fuels and prices of appliances. The consumption of energy in the residential sector is analyzed in chapter II.

The manufacturing sector accounts for more than one-third (36%) of total commercial energy consumed in the country [70]. The structure of demand in the industrial sector has depended on the characteristics of production, particularly on the extent to which capital, labour and energy can be used in different proportions in response to changes in the prices of these factors. Chapter III deals with the industrial sector and obtains estimates of elasticities of substitution between labour, capital and energy as well as own- and cross-price elasticities of these inputs.

⁶ Natural gas and oil used in thermal electricity and natural gas used in fertilizer industry have been subtracted from the estimate of aggregate energy consumption to avoid double counting [70].

A translog cost function is used to estimate the demand for labour, capital, energy, and individual fuels in the industrial sector. First, derivatives of the log of the cost function with respect to the log of the price of each factor are taken to obtain the cost share of each factor. The cost share equations are then used to estimate the demand for factors and fuels and the elasticities of substitution between them.

The transportation sector consumes 61% of the total supply of petroleum products [70]. In terms of the mode of operation and fuel use, the transportation sector has been divided into three sections. In the first section, the demand for gasoline by private automobiles has been analyzed. The model for gasoline demand is similar to the model of demand for fuel in the residential sector. There are many factors that determine fuel demand in other modes of transportation. For estimation purposes, the important factors have been taken to be income, relative prices of fuels, urbanization and the stock of infrastructure. The demand for fuel by airplanes is analyzed in section II and joint demand for buses, trucks, railways and ships in section III. Chapter IV is the subject matter of fuel demand in the transportation sector.

A model for total energy demand has been specified within a general equilibrium framework. The economy has been postulated to consist of producers and consumers. Energy is demanded by producers for purposes of producing commodities and services, and by consumers for heating, cooking, lighting, transportation,

etc.. Demand functions for outputs have been derived by assuming that consumers maximize a neo-classical utility function subject to income constraints, while input demand functions have been derived on the assumption that producers minimize the cost of producing a given vector of outputs subject to a neo-classical production function. After some simplifying assumptions, the total demand for energy has been derived as a function of real income and the real price of energy.

A distinction between short-run and long-run effects of income and price changes is important in the analysis of energy demand. Income effects are considered primarily a short-run phenomenon while price effects are assumed to encompass both a short- and a long-term reaction [51]. In the industrial sector, for example, in the short-term -- when technology and the proportions between the variable factors of production remain constant -- demand for energy will vary with output (income) levels and possibly efficiencies associated with the utilization rate of capacity. In the longer term, energy prices relative to prices of other factors of production will further influence industrial energy demand by changing the existing capital stock.

Similarly, in the residential sector, where the purchases of durable goods may depend on both present and expected income, the actual utilisation of such durable goods -- and hence energy consumption -- will depend on consumer expenditure in each time period. The short-run effect of a price increase would be reflected in a decrease in the consumption of energy while

maintaining the existing stock of durable goods. In the longer-term, conservation could be achieved by switching to more efficient equipment, retrofitting houses etc.

It is generally believed that the income elasticity of demand for commercial energy in UDCs should be higher than in industrialized countries [80]. A large proportion of energy consumption in UDCs has been from non-commercial sources. This proportion, however, steadily declines as urbanization and industrialization proceed. For example, the proportion of non-commercial energy to total energy in Pakistan has declined from 60% in 1960 to 40% in 1981 [70]. Empirically, it has been observed that for a given percentage growth in income in UDCs, there has been more than a proportional increase in the demand for energy [77]. Since the demand for non-commercial energy declines with urbanization, any increase in the demand for energy resulting from an increase in income implies a more than proportional increase in the demand for commercial energy. In developed countries, energy produced from non-commercial sources is negligible since much of their economies are urbanized [80]. It is unlikely that there would be an additional pressure on the demand for commercial energy through substitution from non-commercial to commercial sources of energy. Therefore, the income elasticity of demand for commercial energy in UDCs should be higher than what is observed in the developed countries.

The magnitudes of the price elasticity of energy demand in UDCs is however, difficult to predict. Demand is usually subject

to supply constraints and price regulations in these countries. One can not tell with a priori reasoning whether the price elasticity in UDCs should be greater or smaller than in industrial countries. The fact that UDCs have a relatively small energy-consuming capital stock should make it easier to adjust the total capital stock composition to changes in relative factor prices. However, at low levels of income, most energy is consumed as a necessity. The scope for "doing without" would be much less. At a higher level of income, the additional use of energy becomes more discretionary, allowing for greater substitution if its price rises. This argument suggests that the price elasticity in UDCs should be lower than in industrialized countries.

The long-run income elasticities obtained in this study are greater than unity for most of the fuels consumed. This implies that income is an important determinant of the demand for fuels in Pakistan. The long-run price elasticities of fuel demand, on the other hand, are usually small in value and weak in statistical significance. The main reason for the insignificant estimates of the price elasticities may be the limited variation of fuel prices observed during the period of estimation. This may be due to the fact that the prices of fuels have been regulated in Pakistan. A detailed examination of the prevalent pricing policies is therefore necessary for understanding the nature of energy demand in Pakistan. The pricing and non-pricing policies related to the management of energy demand are in the

Appendix.

The scope of this study has been limited to commercial energy. However, non-commercial sources of energy constitute about 40% of the total energy consumed in Pakistan [70]. Since these energy supplies do not move through monitored distribution channels and markets, there exists a paucity of data on this sector. Therefore, despite the relative importance of non-commercial fuels in Pakistan, they are not considered in the following study.

Energy is measured in terms of thermal content, such as gross billion BTUs. However, different fuels and different uses of the same fuel can involve different thermal efficiencies, and this can make the quantity comparison misleading. The difference in thermal efficiencies can be eliminated by measuring 'net' energy consumption (adjusted for thermal efficiencies) rather than 'gross' energy consumption. There are two problems with this approach. First, it is difficult to obtain reliable estimates of thermal efficiencies. Secondly, fuel choice is based not only on usable thermal content but also on such factors as convenience, controllability, cleanliness and capital costs. A realistic approach would be to include these factors in the measurement of an energy unit, but these factors are difficult to estimate.

Energy consumption in this study is measured in terms of per capita BTU's. This was done because the results obtained by regressing per capita BTU consumption of energy on income and

price of energy were more consistent with a priori knowledge of economic theory and more significant statistically than those obtained from regressing total BTU consumption of energy on the same explanatory variables. However, this measure has some limitations. Non-commercial energy was not included in the estimation of per capita energy consumption due to the unavailability of data. The exclusion of non-commercial energy could affect the results, because with continuous deforestation and increasing urbanization, traditional fuels are replaced by kerosene, electricity or natural gas. This kind of substitution puts pressure on the demand for commercial fuels.

A large proportion of total commercial energy is consumed in urban areas as natural gas, electricity, LPG, motor gasoline, aviation fuel etc.. Per capita energy consumption is estimated by dividing total energy consumption by total population, as excluding the census years, the figures for urban population are not available. For the same reason, national per capita income is used as an explanatory variable instead of urban per capita income.

In UDCs, the rate of growth of national income and the degree of urbanization are highly correlated. With industrialization, people migrate from the countryside to cities. In cities, commercial fuels are the main sources of energy. Therefore urbanization increases the demand for energy. The effect of urbanization on energy demand is captured by the growth of national income.

For estimating the aggregate demand for energy, the price of aggregate energy was estimated by a weighted average price of natural gas, electricity, oil and coal consumed in all sectors of the economy. However, energy is not a single commodity; it is an aggregate of several commodities. To incorporate the opportunity cost and the substitution characteristics of each fuel, the price of aggregate energy should have been calculated by a Divisia index or approximated by an instrumental variable, estimated from the translog cost function of fuel prices (See Pindyck [80]). There are different types of fuels and a particular fuel can be used in more than one sector of the economy. Moreover, the price of a fuel can vary from one level of consumption to the other (blocked prices) and from one sector of the economy to the other. A weighted average price of fuels consumed in different sectors of the economy is therefore considered a simpler way of measuring the price of aggregate energy.

I. HISTORICAL BACKGROUND, DATA AND ESTIMATION

1. Background

The population of UDCs comprises 71% of total world population, but their annual consumption of energy is about 17.5% of global consumption. This is less than half of total commercial energy consumed in the United States alone, which has only 5.5% of the world population [77]. However, the consumption of commercial energy in the UDCs has been growing at a much faster rate than in the developed countries. Before the oil crisis in 1973, the consumption of commercial energy in UDCs was increasing at an average annual rate of 6.9% as compared to 5% for the world as a whole. During the 1980s, consumption of commercial energy in UDCs is projected to grow at 6.2% a year [97].

Table II-1 shows the degree of dependence of the DMCs on oil imports. ¹ In spite of the oil price increases since 1973,

¹DMCs are the 14 member countries of the Asian Development Bank (ADB). On the basis of per capita income, DMCs are grouped in following categories:

I Low Income: Afghanistan, Bangladesh, Burma, Nepal, Pakistan and Sri Lanka.

II Lower- Middle Income: Papua New Guinea, Phillipines and Thailand.

III High and Upper-Middle Income: China, Fiji, Hong Kong, Korea and Singapore [2].

Table I - 1

Energy Imports and External Debt in Relation
to GDP, Exports and Imports, 1970 & 1978

	Energy Imports in total Commercial Energy Consumption in 1978 (%)	Net Energy Imports (%)				External Debt to GDP (%)			
		1970		1978		1970	1978		
		Total Exports	Total Imports	Total Exports	Total Imports				
Pakistan	39.7	9.3	5.7	0.7	35.1	15.3	2.0	22.1	49.3
Low-Income	61.5	9.7	6.7	0.9	23.5	14.4	3.2	20.7	24.0
Lower-Middle Income	96.0	12.2	7.4	1.6	25.1	19.7	5.3	8.0	13.8
High & Upper-Middle Income	89.4	6.4	3.8	2.0	12.5	10.1	5.7	9.2	13.9

Source: Asian Energy Problems [2]

the DMCs have recorded an average annual growth rate of 6.5% in GDP during 1973-78 [2]. This growth in GDP was possibly because of good harvests, an increase in demand for their exports, and substantial revenues remitted from their labourers working in the Middle East. However, this improvement in GDP was not without problems. It created deficits in the balance of payments of the DMCs and raised the level of their foreign debt. As can be observed from Table I-1, external debt in relation to GDP increased for all categories of countries in the DMC from 1970 to 1978. Pakistan was the hardest hit with its percentage of external debt to GDP rising from 22.1% in 1970 to 49.3% in 1978. Part of the problem was that net energy imports as a percentage of total exports, imports and GDP also increased in most of the DMCs, especially in Pakistan where energy imports as a percentage of total exports increased from 9.3% in 1973 to 35.1% in 1978.

ADB has estimated the consumption of commercial energy and the energy/GDP elasticity for DMCs. See Table I-2. The average rate of growth of consumption of commercial energy was about 8.5% per year during 1973-78 with a commercial energy/GDP elasticity of 1.2. Since every country faces a unique set of conditions, including its level of income, degree of industrialization and its energy resource endowment, the rate of growth of consumption of energy and the GDP elasticity varies widely among these countries. For example, the annual rate of growth of commercial energy in Pakistan, as estimated by ADB,

Table I - 2

Annual Growth Rates and GDP Elasticities of
Commercial Energy Consumption in DMCs

	<u>All Countries</u>	<u>Pakistan</u>	
		<u>ADB Study (1973-78)</u>	<u>This Study (1960-81)</u>
Gross Domestic Product:			
Average Rate of Growth (%)	7.1	4.9	9.9
Petroleum:			
Average Rate of Growth (%)	9.0	4.7	7.5
GDP Elasticity	1.3	1.0	0.8
Natural Gas:			
Average Rate of Growth (%)	10.0	2.1	4.2
GDP Elasticity	1.4	0.4	3.5
Electricity:			
Average Rate of Growth (%)	12.7	10.7	15.0
GDP Elasticity	1.8	2.2	2.5
Coal:			
Average Rate of Growth (%)	4.8	-1.9	-0.4
GDP Elasticity	0.7	-0.4	-0.7
Total Commercial Energy:			
Average Rate of Growth (%)	8.5	3.5	3.4
GDP Elasticity	1.2	0.7	1.2

Source: Asian Energy Problems [2].

was 3.5% and the elasticity was 0.7 during 1973-78, as compared to another member of the DMCs, such as Sri Lanka, where growth in the consumption of commercial energy was 1.5% and the elasticity was 0.3 during the same period [2].

The results reported for Pakistan in this study will turn out to be different from those obtained in the ADB's study. The differences are due to the following reasons: the ADB's study is based on pooled time series data of 6 years for a cross-section of 14 countries, while this study is a pure time series study based on annual observations of 22 years in Pakistan. The ADB study uses a simple linear regression between the consumption of energy and GDP. The results in this study are obtained by estimating a multiple log-linear regression between the consumption of energy, GNP, prices of energy and energy consumption lagged one period. The percentage growth rate in the consumption of natural gas and its GDP elasticity are especially distinguishable between the two studies. This was due to high rate of growth of consumption of natural gas (8.4% per year) during 1978-81, which was not included in ADB's study.

The energy balance sheet of Pakistan for the year 1981 is shown in Table I-3. During 1981, commercial energy consumption in Pakistan was 420,887 billion BTU, implying a per capita consumption level of about one-tenth of the world average, one-half of the average for all UDCs, one-quarter of that of most Asian countries and one-sixteenth that of the United States [26]. Natural gas has the highest percentage share in the supply

Table I - 3

Energy Balance Sheet of Pakistan, 1981

	<u>Thousand Tons of Oil Equivalent</u>	<u>% of Total Supply</u>
<u>Oil:</u>		
Indigineous Production	406.0	6.8
Imported Crude Oil	3631.1	60.8
Imported Petroleum Products	1605.6	26.9
Total Supply	5962.9	
Less Export	1094.5	18.0
Less Closing Stock/Losses	463.3	7.7
Consumption	4405.1	73.9
<u>Gas:</u>		
Gas Processed	5490.3	86.5
Raw Gas	484.7	7.6
Associated Gas	366.8	5.7
Total Supply	6341.9	
Less Feed Stock/Losses	1183.1	18.0
Consumption	5158.8	81.3
<u>LPG:</u>		
Supply/Consumption	42.1	
<u>Coal:</u>		
Supply/Consumption	705.5	
<u>Electricity:</u>		
Hydle Generation	2152.2	56.3
Thermal Generation	1634.8	42.7
Nuclear	35.8	0.9
Total	3822.7	
Less Losses	1113.2	29.1
Consumption	2709.5	70.8
<u>Total Commercial:</u>		
Total Availability	16875.2	
Less Feed Stock/Losses	2632.8	15.6
Less Export/Auxiliary	1221.4	7.2
Consumption	13021.0	77.1

Source: Energy Year Book, 1981 [70]

of commercial energy, followed by oil. The percentage share of coal in total energy supply is decreasing rapidly, from 60% in 1948 to 4% in 1981 [71]. This decrease was due to the discovery of natural gas in 1952 and rapid development of its consumption in residential and industrial sectors of the economy. Before the energy crises in 1973 and the subsequent price hikes of imported oil, oil was the most important single source of commercial energy. In 1961 its share was 62% [72]. An intensive substitution towards indigenous sources of energy, natural gas and electricity, has resulted in the share of natural gas and electricity increasing to 38% and 22% respectively during 1981. The share of oil decreased to 35% in the same year. [70].

A break down of the sector-wise consumptions of different types of fuels for the three years, 1961, 1971 and 1981 is given in Table I-4. In 1981, the transport sector was the principal consumer of energy followed by the residential and the industrial sectors. The industrial sector has undergone a substantial growth in the consumption of energy in the last 21 years, especially of natural gas. The use of natural gas, primarily consumed in the residential and the industrial sectors of the economy, increased from 9.5% in 1961 to 38% in 1981. This has raised the percentage share of energy consumed in the residential and industrial sectors and lowered the share of energy consumed in the transport sector. However, the transportation sector accounted for 68% of total petroleum product consumption in 1981. The consumption share of commercial

Table I - 4

Sector-Wise Consumption of Commercial Energy
(Billion BTU and Percentages)

	1961		1971		1981	
	Quantity	(%)	Quantity	(%)	Quantity	(%)
<u>Residential:</u>						
	8963.8	(7.8)	26890.1	(11.7)	65492.5	(15.3)
Natural Gas	393.9	(4.4)	3385.9	(12.6)	24770.7	(37.8)
Electricity	1098.1	(12.2)	5329.2	(19.8)	15943.1	(24.3)
Kerosene	6851.1	(76.4)	17500.9	(65.1)	22746.2	(34.7)
LPG	-	(-)	93.8	(0.3)	1886.9	(2.9)
Coal	620.7	(6.9)	580.3	(2.2)	145.6	(0.2)
<u>Industrial*:</u>						
	43684.5	(37.9)	98089.6	(42.6)	201638.7	(46.9)
Natural Gas	10629.1	(24.3)	56124.6	(57.2)	146589.4	(72.7)
Electricity	2099.7	(4.8)	8526.1	(8.7)	15442.3	(7.6)
Coal	25242.1	(57.8)	24188.9	(24.7)	28974.6	(14.4)
FO	5713.6	(13.1)	7946.7	(8.1)	8324.6	(4.1)
HSD	-	(-)	1163.2	(1.2)	2232.9	(1.1)
LDO	-	(-)	140.1	(0.1)	74.9	(0.03)
<u>Transport:</u>						
	56309.7	(48.9)	87394.7	(38.0)	127763.4	(29.7)
Motor Fuel	7880.4	(14.0)	13745.6	(15.7)	26979.4	(21.1)
Aviation Fuel	6367.1	(11.3)	16664.7	(19.1)	23545.5	(18.4)
FO	28227.3	(50.1)	28240.4	(32.3)	20396.7	(15.9)
HSD	10297.6	(18.3)	27708.7	(31.7)	56199.8	(44.0)
LDO	283.2	(0.5)	536.2	(0.6)	642.0	(0.5)
Coal	3254.1	(5.8)	499.1	(0.6)	-	(-)
<u>Agriculture:</u>						
	6187.3	(5.3)	17576.8	(7.6)	34513.1	(8.0)
Electricity	348.6	(5.6)	3659.6	(20.8)	7287.6	(21.1)
HSD	404.7	(6.5)	4567.3	(25.9)	20124.6	(58.3)
LDO	5434.0	(87.8)	9349.9	(53.2)	7100.9	(20.5)
<u>Total</u>	115145.3		229951.2		429407.7	

* Consumption in all industrial sectors, including cement, fertilizer and Power.

Sources: Pakistan Energy Year Book, 1981 [70]
Energy Forecasting Model [72]

energy in the agricultural sector has increased from 5.3% in 1961 to 8% in 1981 due to mechanization.

2. Data

Annual data for the period 1960 to 1981 are used in the estimation of energy demand in this study. Data on consumption and the prices of fuels were obtained from Energy Data Book, 1979 [71], Energy Year Book, 1981 [70] and Energy Forecasting Model [72]. Data for gross national product, population, and the wholesale consumer price index (based on 1959-60=100) are taken from Pakistan Economic Survey, 1981-82 [66].

The data used in this study will be discussed in two parts. The first part explains the measurement of quantities and the prices of fuels used in the models of the residential and transportation sectors and the aggregate economy. The variables and the regression techniques employed to estimate the energy demand in these sectors are similar in their characteristics. The second part discusses the data and the method of estimating energy demand in the industrial sector.

Income: Income is expressed in real per capita terms. It is estimated by first dividing total GNP at current prices by total population and then deflating this estimate of per capita income by the wholesale consumer price index based on 1959-60=100.

Per capita real urban income is obtained by the same method as above, except that urban GNP and urban population are used in

the calculation. Urban GNP is computed by subtracting agricultural income from total GNP. Figures for urban population for 1961, 1972 and 1981 have been taken from the Censuses. For the inter-censal periods, figures are estimated by multiplying the population of urban centers of Pakistan by its annual average compound growth rate of 5% for 1961 to 1972 and 4% for 1972 to 1981. (See [65] for further explanation).

Quantities: All fuel consumption was first measured in billions of BTUs and then converted to per capita terms.² The per capita consumption of a fuel is obtained by dividing total consumption of the fuel by total population.

Fuels used by the residential sector were divided into two groups: the first group includes natural gas, LPG and electricity as GASEL, and the second group includes coal and kerosene as COLKERO.³ Total consumption of fuels of each group is obtained by adding up the BTUs of the respective fuels of the group.

Total consumption of fuels in the transportation sector is also divided into two groups. The first consists of fuels consumed by automobiles and airplanes, and the second of fuels consumed by buses, trucks, railways and ships. Gasoline use by automobiles and aviation fuel used by airplanes are expressed both in terms of national per capita consumption and urban per

² See pp. 15 for an explanation.

³The reasons for dividing the residential consumption of fuels into two groups are described in chapter II, pp. 33-34.

capita consumption. The consumption of fuels by the other modes of transportation (buses, trucks, railways and ships) are estimated by adding up the consumption of HSD, LDO, FO and coal consumed in the transportation sector and expressed in per capita terms.

Aggregate demand for energy includes all types of commercial fuels consumed in all sectors of the economy. It is obtained by first adding up the consumption of a 'given' fuel in the residential, industrial, transportation, agricultural and other sectors of the economy, and then adding up the total consumption of 'all' types of fuels in these sectors.

Prices: The prices of fuels are given in Rupees per mmBTU. These prices are expressed in real terms by deflating with the whole sale consumer price index based on 1959-60=100.

The prices of GASEL and COLKERO in the residential sector are a weighted average of the prices of the fuels in this sector. The weight for a fuel belonging to a group is determined by the (physical) percentage share of that fuel in the total consumption of all fuels in that group in the residential sector.

A weighted average of the prices of HSD, LDO, FO and coal consumed by buses, trucks, railways and ships in the transportation sector was also used. The weight for a fuel was again its percentage share in the total amount of these fuels consumed in the transportation sector.

The price of a 'given' fuel varies from sector to sector. The price of a given fuel used in the total energy demand model was a weighted average of the prices of that fuel in the residential, industrial, transportation and agricultural sectors. The weight was the percentage share of consumption of a particular fuel in 'one' sector relative to the consumption of that fuel in 'all' sectors of the economy.

The price of 'all' fuels in the total energy demand model is the (sectoral) weighted average of the weighted average of the prices of all types of fuels. It is estimated by first taking an average of the weights of the consumption of a 'given' fuel in the different sectors of the economy. The weight was the percentage share of consumption of a fuel in 'one' sector relative to all other sectors. Then the average was taken of the weights of all fuels consumed in all sectors of the economy. The weight was the percentage share of consumption of a fuel relative to the total consumption of all fuels in the economy.

3. Estimation

The models for the residential, transportation and aggregate energy demand show that real income and real prices are the two main economic variables influencing the demand for energy. However, there is a time lag in the response to changes in these two variables, as described in the earlier chapter, pp. 11-12. Income has primarily a short-run impact on demand while

price was assumed to induce both short- and long-term reactions [51]. Generally there are two common specifications for the lag-structure: (a) the Koyck or geometric lag and (b) the Almon or polynomial lag. In general form, the two equations can be written as:

$$f_{ij,t} = \phi \beta_0 + \phi \beta_1 p_{ij,t} + \phi \beta_2 y_{i,t} + (1-\phi) f_{ij,t-1} + \epsilon_t \quad (1)$$

$$f_{ij,t} = \beta_0 + \beta_1 \sum_{k=1}^{t-1} \phi^k p_{ij,t-k} + \beta_2 y_{i,t} + \epsilon_t \quad (2)$$

where,

$f_{ij,t}$ is consumption of i th fuel in j th sector at time t .

$p_{ij,t}$ is the price of i th fuel in j th sector at time t .

$y_{i,t}$ is income spent on i th fuel at time t .

ϕ is the adjustment lag coefficient.

ϵ is error term.⁴

In the geometric lag specification, Eq.(1), a dynamic adjustment process is implied in which the impact on demand of a price increase declines geometrically as times passes. The geometric lag distribution puts an implausible prior restriction on the relative magnitude of these adjustments. It also assumes the same time path of adjustment to income and price changes. In reality, the nature of adjustment to income could be entirely different from that to prices. The geometric lag has the

⁴For OLS to be the optimal estimator it is assumed that the mean of the error term is zero, its variance is constant and errors are not correlated with one another [24].

advantage of being extremely parsimonious in the use of variables. However, the statistical disadvantage is that if the errors are autocorrelated, the estimates of coefficients are biased and inconsistent [55].

The polynomial distributed lag model, Eq(2), assumes an instantaneous adjustment to income changes and can accommodate any time path of adjustment to price changes. Another advantage of this technique is that it leads to unbiased estimates of coefficients. The disadvantage of the polynomial lag structure is that the length of the sample is seriously reduced if either the sample period is short or if the duration of the lag is too long [55].

To obtain estimates of the income and price elasticities of residential, transportation and aggregate energy demand, both Eqs.(1) and (2) are estimated by the Ordinary Least Squares (OLS) method. Since the sample period is short, 1960 to 1981, and the price coefficients of energy demand, estimated by Eq.(2) were statistically insignificant at different lags, Eq.(1) was considered more useful for analyzing energy demand in Pakistan.

The OLS method may have some shortcomings: First, the presence of a lagged dependent variable on the right hand side of the equation results in interdependence of the lagged variable with the error term. As a result estimates produced by OLS may be biased and inconsistent. Generally for large samples, instrumental variable or error component methods are possible alternative techniques for estimation [56]. The method of

instrumental variable was also used to estimate the fuel demand equation.⁵ However, the parameters produced by this method were statistically less satisfactory than the OLS estimates.⁶ This was due to the large standard errors of the parameter estimates, perhaps resulting from low correlations of the instrumental variables with the regressors. Moreover, the three lagged values of regressors, used as instrumental variables, were estimated by 19 observations. Thus there was a problem of lack of degrees of freedom [53].

The second problem with the OLS estimation technique is that the regressor lagged dependent variable makes the DW test for serial correlation invalid. Durbin has proposed an alternative test, known as the Durbin h-test. The values of the h-statistic correspond to the standardized normally distributed Z-test statistics. Therefore, the hypothesis that the disturbances are free of first order correlation at the 5% level of significance is accepted when the calculated value of the h-statistic lies between +1.96 and -1.96 [24]. If this test failed then the equation was reestimated by the Generalized Least Squares (GLS) method to obtain non-serially correlated

⁵The error component method has restrictive application to pooled time-series of cross-section data [56].

⁶ Lagged values of income and price were used as instruments to estimate the parameters under the instrumental variable method. The number of lags was decided on the basis of improvement in the fit as additional lagged values of the explanatory variables were introduced [53].

residuals.⁷

Industrial Sector

Energy demand in the industrial sector was modelled using a translog cost function. A system of share equations was estimated to obtain the price elasticities and elasticities of substitution of demand for energy by this sector. The iterative Zellner method of estimation was used to estimate the share equations, because the OLS method produces inconsistent estimates of the coefficients. The concept and method of estimation of energy demand in the industrial sector is explained in more detail in chapter III.

⁷The residuals are modelled as an autoregressive process of order one.

II. DEMAND FOR ENERGY IN THE RESIDENTIAL SECTOR

1. Model

The model of residential demand for fuel is based on the postulates of the traditional micro economic theory. ¹ A consumer's objective is to maximize utility, subject to a budget constraint. In this study, an additional constraint is imposed: the amount of fuel consumed is less than or equal to the 'capacity' -- measured in BTU -- of the consumer's stock of appliances. ² This stock is in turn dependent on the price of fuel, prices of appliances and the real income of the consumer.

Therefore, if 'F' stands for the demand for fuel, ' ' for the rate of utilization of appliances -- assumed to be constant and the same for all appliances -- and 'K' for the stock of appliances, the demand equation can be expressed as:

$$F = \delta K \quad (1)$$

¹See Houthaker et.al. [41], Taylor [85] and Murray et.al. [62].

²This is due to the fact that demand for energy is a derived demand: users do not demand energy because of any intrinsic utility it possesses but rather because it is essential for the provision and consumption of goods and services.

In the log-linear form, Eq.(1) can be written as ³:

$$f = \delta' + k \quad (2)$$

Further, we assume that ' δ' ' is a log-linear function of m -variables, the ' X_i ' (income, relative prices of different kinds of fuel, temperature, etc.) as:

$$\delta' = \sum_{i=1}^m \alpha_i X_i + u \quad (3)$$

where u is the random error in the logarithmic form.

Substituting Eq.(3) into Eq.(2):

$$f = \sum_{i=1}^m \alpha_i X_i + k + u \quad (4)$$

Or

$$k = f - \sum_{i=1}^m \alpha_i X_i + u \quad (5)$$

To eliminate the need for data on ' K ', we assume that the consumer is in the process of continuous partial adjustment towards a desired level of appliance holdings, K^* . ⁴ K^* is assumed to depend on l -variables, ' Y_j ', all of which may have appeared in ' X_i '.

³Lower case letters stand for logarithms of economic variables. The logarithmic specification yields better results in terms of the significance of the estimated parameters. It has the added advantage that the coefficients are interpretable as demand elasticities [41].

⁴ Consumers react to price change by continuously adjusting actual purchases of durable goods to some desired stock over time. However, the nature of the acquisition process is often one of discrete consumer choices, where the consumer either has or does not have a given appliance. Aggregation over discrete consumer decisions may produce a smoothing effect on a market level response function [11].

In the log-linear form, this can be written as:

$$k^* = \sum_{j=1}^l \beta_j y_j + e \quad (6)$$

where e is the random error in logarithmic form. We also assume that the partial adjustment process takes the form :

$$k_t - k_{t-1} = \phi (k_t^* - k_{t-1}) \quad (7)$$

where $0 < \phi \leq 1$.

Substituting Eq.(5) into Eq.(7):

$$\begin{aligned} f_t - \sum_{i=1}^m \alpha_i x_{it} - u_t - f_{t-1} + \sum_{i=1}^m \alpha_i x_{it-1} + u_{t-1} \\ = \phi k_t^* - \phi f_{t-1} + \phi \sum_{i=1}^m \alpha_i x_{it-1} + \phi u_{t-1} \end{aligned} \quad (8)$$

After some rearrangement and substituting Eq.(6) into Eq.(8):

$$\begin{aligned} f_t = \phi \sum_{j=1}^l \beta_j y_{jt} + \sum_{i=1}^m \alpha_i x_{it} + (1-\phi) f_{t-1} \\ - (1-\phi) \sum_{i=1}^m \alpha_i x_{it-1} - (1-\phi) u_{t-1} + \phi e_t - u_t \end{aligned} \quad (9)$$

Assume that $x_{it} = x_{it-1}$ and $u_t = u_{t-1}$ ⁵

Eq.(9) can be written as:

$$\begin{aligned} f_t = \phi \sum_{j=1}^l \beta_j y_{jt} + (1-\phi) \sum_{i=1}^m \alpha_i x_{it} + \phi \sum_{i=1}^m \alpha_i x_{it} \\ + (1-\phi) f_{t-1} - (1-\phi) \sum_{i=1}^m \alpha_i x_{it} + \phi v_t \end{aligned} \quad (10)$$

⁵The best indicator of the expected value of a variable is its current and past values. This is specially true for the income and energy price in Pakistan. The weighted average price of energy remained constant during the period from 1960 to 1968 and again from 1969 to 1979 [72]. The real per capita income increased but at almost constant rate of 3.5% annually from 1960 to 1981 [66]. Therefore, the assumption that x_t is not different from x_{t-1} is not unreasonable.

where $v_t = u_t + e_t$.

Or

$$f_t = \phi \left(\sum_{j=1}^l \beta_j y_{jt} + \sum_{i=1}^m \alpha_i x_{it} \right) + (1-\phi) f_{t-1} + \phi v_t \quad (11)$$

If the stock of appliance holding and its rate of utilization include the same explanatory variables, viz. income, (Y), weighted average real price of gas and electricity (PGASEL), and weighted average real price of coal and kerosene (PCOLKERO), Eq.(11) can be simplified as: ⁶

$$f_t = \phi \gamma_0 + \phi \gamma_1 y_t + \phi \gamma_2 p_{gasel,t} + \phi \gamma_3 p_{colkero,t} + (1-\phi) f_{t-1} + \phi v_t \quad (12)$$

The estimation of Eq.(12) will yield short-run income and price elasticities as these are the coefficients of income $\phi \gamma_1$ and price $\phi \gamma_i$, $i=2,3$. The long-run demand elasticities can be derived by removing the adjustment-lag from the equation.

⁶(1) Due to the absence of data on the prices of fuel-consuming appliances, the prices were not included in the present estimation. This omission is not expected to affect the regression results much. The expenditures on appliances are fixed costs, whereas the prices of fuels are variable costs. The rate of utilization of appliances and thereby the consumption of fuels are determined mainly by variable costs.

(2) In the original equation, temperature and trend variables were included to capture the influence of weather and changes in taste and preferences. Both variables were dropped later due to low values of the parameter estimates and their poor significance levels.

To do this, we first estimate the coefficient of the lagged consumption term $(1-\phi)$. Then we remove the adjustment rate from the short-run elasticities as:

$$\eta_{fy} = \phi \gamma_1 / \phi \quad (13)$$

$$\eta_{fp} = \phi \gamma_i / \phi \quad i=2, 3 \quad (14)$$

η_{fy} is the long-run income elasticity and η_{fp} is the long-run price elasticity of fuel consumption [7].

2. Regression Results

Two different versions of Eq.(12) have been estimated. In the first version, total residential consumption of all fuels is divided into two groups. The first group includes natural gas, LPG and electricity as GASEL, and in the second group, coal and kerosene are treated together as COLKERO. This is due to the fact that the percentage share of natural gas, LPG and electricity in the residential consumption of all fuels has increased at an annual rate of 14% as compared to a 3% increase in the share of coal and kerosene over the last twenty-two years. Similarly, consumption of gas and electricity has grown by 150% over the same period as against a 11% increase in coal and kerosene [68]. Moreover, natural gas, LPG and electricity as a group are substitutes for coal and kerosene. An earlier study on the consumption of natural gas and electricity in the residential sector of Pakistan has shown that natural gas and

electricity were complements to each other [43]. Therefore, by doing this we can test the hypothesis that the income elasticity estimate of COLKERO is different from the income elasticity estimate of GASEL. In each regression equation, prices of COLKERO and GASEL are included to test whether the two fuels are substitutes or complements.

In the second version of the model, two equations are estimated. In the first equation, consumption of GASEL and COLKERO are summed up as ALLFUEL and (separate) prices of GASEL and COLKERO are used as regressors in addition to income and lagged dependent variable. The hypothesis tested is whether the consumption level of energy changed during the period of study, taking (a) each fuel separately and (b) all fuels jointly. The second equation is the same as the first, except that the individual prices of GASEL and COLKERO are replaced by a weighted average price. Using a weighted average price increases the degrees of freedom and reduces the problem of multicollinearity. As a result, this improves the statistical significance of parameter estimates.

The OLS technique is applied to estimate per capita consumption of fuel. The results are given in Table II-1. The regression results show that the sign of the income elasticity of GASEL, COLKERO and ALLFUEL is consistent with economic theory. The income elasticity estimates for GASEL and ALLFUEL are significant at less than the 5% level. The income elasticity estimate for COLKERO is relatively small and barely significant

Table II - 1

Regression Results of Residential Demand for Fuel in Pakistan (1961-81)

Regression Equations	Variables	Intercept	Income	Price of GASEL	Price of COLKERO	Price of ALL FUEL	Lagged Variable	R ²	F(4/16)	h-stat/DW
<u>OLS:</u>										
(1)	ALL FUEL	-2.33 (2.04)	1.23 (2.53)	-0.098 (1.26)	-0.076 (1.31)		0.47 (2.38)	0.98	319	0.98
(2)	ALL FUEL	-3.46 (2.77)	1.42 (3.06)			-0.205 (2.43)	0.46 (2.71)	0.98	478	-0.57
(3)	GASEL	-4.57 (2.17)	1.13 (2.33)	-0.101 (1.58)	-0.001 (0.02)		0.73 (7.00)	0.99	1705	-0.86
(4)	COLKERO	0.19 (0.17)	0.64 (1.68)	-0.017 (0.17)	-0.309 (3.51)		0.51 (2.27)	0.92	46	-5.79
<u>GLS:</u>										
(5)	COLKERO	0.20 (0.23)	0.57 (1.66)	-0.020 (0.25)	-0.303 (3.96)		0.55 (2.74)	0.94	75	1.98 (p=0.11)

Note: Figures in parentheses are calculated t-statistics.

at the 10% level. This supports the hypothesis that natural gas and electricity are superior fuels to coal and kerosene. Natural gas and electricity are more hygienic in use. They are also more efficient in burning and in operating appliances. With increasing incomes, households tend to switch from coal and kerosene to gas and electricity, or at least cut down expenditures on the former.⁷

In this study, the estimates of the long-run income elasticity (2.27) for Pakistan, shown in Table II-2, are higher than those obtained for other developed countries. For instance, the long-run income elasticity for total energy demand ranges from 1.22 to 1.71 in the study done by Wolf and others [95]. Hoffman [39] reports a long-run income elasticity of 1.19 for South Asian countries. This difference in the elasticity estimates may be due to several factors. First, our estimate for income elasticity is based on commercial fuels used in the residential sector only, while studies for other developing countries have estimated income elasticities for commercial and non-commercial fuels consumed jointly in all sectors of the economy. Since there is considerable substitution within different types of fuels in total energy consumption, the income elasticity would be smaller for aggregate energy consumption

⁷ For example, in Pakistan, 2% of the annual household expenditures were assigned to kerosene at lower level of income (Rs.600 a year). It dropped to nil at higher level of income (Rs.24000 a year); expenditures on natural gas and electricity increased from 0.8% to 3% for the same cross-section of the population [68].

Table II - 2

Short- and Long-Run Income and Price Elasticities

	<u>ALL FUEL</u>	<u>GASEL</u>	<u>COLKERO*</u>
Income			
Short-run	1.23	1.13	0.57
Long-run	2.27	4.18	1.26
P_{gasel}			
Short-run	-0.09	-0.10	-0.02
Long-run	-0.17	-0.37	-0.04
P_{colkero}			
Short-run	-0.08	-0.001	-0.30
Long-run	-0.15	-0.037	-0.66
P_{allfuel}			
Short-run	-0.20		
Long-run	-0.37		

* Estimated from the GLS regression results.

Source: Table II - 1.

than for consumption in a particular sector of the economy [39].

Secondly, gas, electricity and even kerosene are not the basic household fuels in Pakistan. The vast majority of consumers rely on non-commercial sources of energy for cooking, heating, etc. [73]. Commercial fuels are consumed mainly in urban centers whereas national per capita income (instead of urban per capita income) is used to estimate the fuel demand. As a result, the income elasticity estimates may be biased upward⁸.

Thirdly, urban migration is a contributing factor to the rapid growth of household commercial energy demand. In rural areas, where a greater proportion of energy use is non-commercial, household energy demand is likely to be very price inelastic, but also relatively income elastic. In urban areas, household demand is likely to be much more income elastic since a larger share of any increase in consumption expenditures will be allocated to housing and the associated use of commercial energy. This means that urban migration could increase commercial energy demand at any level of income [80].

The own-price elasticities of GASEL and COLKERO are negative and statistically significant at the 10% level. The value of price elasticity is somewhat lower than those reported for developed countries [79]. This can be explained by the fact that at low levels of income, most energy is consumed as a

⁸ Urban population and urban income can be estimated from the formula given in pp. 21-22. However, these estimates are not very reliable.

necessity and as incomes grow, the additional use of energy becomes more discretionary. Therefore, at higher levels of income, there would be greater substitution of one form of energy for another due to a rise in the prices of fuels. This would produce higher price elasticities of energy demand in developed countries. The estimates of price elasticity for Pakistan are close to those obtained in studies for other developing countries. ⁹

The negative signs of the cross-price elasticities of GASEL and COLKERO suggest that the two fuels are not substitutes. However, their t-values are small. It appears that consumers have not shifted completely to modern appliances, operated by gas and electricity. They still hold some old stock, using coal and kerosene as fuels.

The price elasticities of GASEL and COLKERO in the equation of ALLFUEL (Reg.Eq.1) are small and statistically not very significant. This may be due to multicollinearity between the two types of fuel prices. When this equation was estimated with a weighted average price of both fuels, the price elasticity appeared as an important variable, with a 1% level of significance (Reg.Eq.2). This suggests that a weighted average price of all fuels is a better measure for the aggregate analysis of fuel consumption in the residential sector.

The income and price elasticities of GASEL and COLKERO are markedly different from each other. The long-run elasticity

⁹See, for example, Hoffman [39].

estimates of ALLFUEL represent an average measure of the two groups of fuels. Therefore, the hypothesis that the consumption pattern of the two types of fuel is the same is rejected. GASEL and COLKERO are consumed by two distinct groups in the country, who are different in terms of the stock of appliances, standard of living, pattern of consumption and accessibility to the fuel market. ¹⁰ Natural gas, LPG, and electricity are restricted to the urban population due to limited supply and distributional bottlenecks. Coal and kerosene are consumed mainly by the rural population [73]. These differences result in the income and price elasticities of GASEL and COLKERO being notably different from each other (See Reg.Eqs.3 and 4).

The values of the h-statistic show that, except for COLKERO, all equations estimated by OLS are free of first-order serial correlation at the 5% significance level [24]. To obtain more reliable parameteric estimates of COLKERO, the Generalised Least Squares method was used. A low income elasticity in the GLS estimate strengthened the hypothesis that the consumption of coal and kerosene increased at a rate less than the rate of growth of income. The R-square and F-ratio are sufficiently high for all the regression equations estimated.

¹⁰It must, however, be noted that within urban areas, there is a large group of consumers who possess traditional lighting and cooking instruments, operated by coal and kerosene. A study by Sherman [83] on energy consumption in Pakistan, which does not include electricity consumption, shows that annual per capita consumption of all other fuels (including non-commercial fuels) is 3.8 Giga-Joule in urban areas compared to 5.4 Giga-Joule in rural areas.

III. DEMAND FOR ENERGY IN THE INDUSTRIAL SECTOR

Traditionally, economists recognize three primary factors of production: labour, capital and natural resources. The latter was quietly dropped when the Cobb-Douglas (C-D) production function was introduced in 1928. The C-D function is a very restrictive theoretical description of production technology. Under this specification, the elasticity of substitution between any pair of factors must be identically unity. In 1961, Arrow and others proposed a more general function, the Constant Elasticity of Substitution (CES) function. Under this specification, the elasticity of substitution between pairs of inputs is allowed to differ from unity. However, in a multifactor case, the CES form is undesirably restrictive because of the a priori imposition of separability conditions on certain inputs and because of an a priori requirement that substitution elasticities stand in fixed ratios to one another.

In 1971, Christensen, Jorgenson and Lau [18] developed a more general flexible function that explicitly included other factors beside labour and capital. A particular version of this function is the transcendental logarithmic production function or simply the translog function. The translog function imposes no a priori restrictions on substitution elasticities beyond those which arise from the assumption of optimizing behaviour. The explicit theoretical specification of the function has the

additional advantage that its constrained version decreases problems of multicollinearity by decreasing the number of parameters to be estimated.

With the advances in duality theory, the translog production function can be replaced by transcendental logarithmic or a translog cost function. When the production function is unknown, use of the cost function circumvents both the statistical problems associated with direct estimation of the production function and the computational difficulties in obtaining input demand functions for estimation. The input demand functions are more easily derived with the dual approach -- Shephard's Lemma -- than in the traditional constrained optimization approach [54].

1. Model

Before formulating a translog function, a simple theoretical exposition of the problem will be given. Consider a cost minimizing competitive firm, which is initially in equilibrium. The firm possesses a positive, twice differentiable, strictly concave production function with three inputs: capital, labour and energy. Next, assume that the price of one of the inputs changes relative to others, e.g. the price of energy rises. The total effect of this on the demand for other factors can be decomposed into two parts. First, there will be a 'substitution effect', where output remaining constant, the use of the relatively higher priced factor will decrease and the use of other factors will increase [54].

Second, there will be an 'output effect', where the factor proportion remaining constant, output will decrease in response to an increase in the price of the factor. If the positive substitution effect outweighs the negative output effect, one would observe a fall in the use of the factor for which the price increased. If, on the other hand, the negative output effect outweighs the positive substitution effect, one would observe an increase in the use of the factor whose price increased [54].

Actually, the economic consequences of a given increase in

energy price will depend on three basic factors: ¹ (a) the value share of energy in output, (b) the percentage increase in the price of energy and, (c) the elasticity of substitution of non-energy factors for energy. If the elasticity of substitution between energy and non-energy factors is zero, an increase in the price of energy will not be absorbed by an increase in the use of non-energy factors nor by a decrease in the initial consumption of energy. As a result, this higher cost of energy would be absorbed only by a reduction in the level of output by means of an increase to proportion in the cost of energy.

If the elasticity of substitution between energy and non-energy factors is unity, for any given increase in the price of energy, there will be a proportional reduction in its consumption, which is just matched by a proportional expansion in the demand for non-energy factors. The output and the value share of energy would remain unaffected.

In the case where the elasticity of substitution lies between unity and infinity, for a given increase in the price of energy, there will be a greater than proportional reduction in the use of energy and its value share and a greater than proportional expansion of the non-energy value share, even though the level of output remains the same.

For values of the elasticity of substitution that range between zero and unity, substitution between energy and non-energy factors is possible, but the extent will always be

¹ This is shown mathematically in a later part of the analysis.

proportionally less than the given increase in the price of energy. A limited shift in non-energy factors means that there will be an increase in the value share of energy which at the same time will result in some reduction in the level of output. The closer the elasticity of substitution approaches a value of one, for a given increase in price, the smaller will be the adverse impact on output and the more likely will be the constancy of the value share of energy.

Going back to the translog function, assume initially that there exists a twice differentiable aggregate production function with four inputs: capital(K), labour(L), energy(E) and materials(M) in the manufacturing sector. ²

$$Q = f(K, L, E, M) \quad (1)$$

where Q is gross output.

First assume that capital, labour and energy inputs are as a group weakly separable from the fourth input, material. Material includes intermediate inputs as well as non-energy raw materials. Weak separability here means that the marginal rate of substitution between any two of the first three inputs is independent of the quantity of material (M) used as an input. This is a necessary and sufficient condition for the production function to be of the form:

$$Q = F[f(K, L, E); M] \quad (2)$$

²See Berndt and Christensen [8], Fuss [29], Pindyck [79;80] and Uri [90].

This assumption is made necessary by the fact that we have no data from which to construct price indices of material inputs and therefore we can only estimate the unrestricted elasticities of substitution between capital, labour and energy. ³

We also assume that any technical change affecting capital, labour, energy and material is Hicks-neutral. ⁴

If factor prices and output levels are exogenously determined, the theory of duality between cost and production implies that the characteristics of production implied by Eq.(2) can be uniquely represented by a cost function that is also weakly separable, that is, a function of the form⁵:

$$C = g(P_K, P_L, P_E; P_M, Q) \quad (3)$$

where C is the total cost and P_K, P_L, P_E and P_M are the input prices of K,L,E and M, respectively.

By a Taylor series expansion, Eq.(3) can be approximated by a translog second-order, twice-differentiable, non-homothetic cost function that does not place a priori restrictions on the

³'Unrestricted' means that material is weakly separable from other factors in the production function; therefore, any change in its marginal product would not affect the estimation of elasticities of substitution of other factors.

⁴ Hicks-neutral technical change implies that for a given ratio of quantities of two factors, the marginal rate of substitution between factors is unchanged. All that happens is that the isoquants are renumbered (each isoquant gets a higher output index each year), and the marginal product of each factor (for given factor supplies) rises by the technical change each year [54].

⁵It is more appropriate to make prices exogenous than quantities [79].

Allen Partial Elasticity of Substitution (AES).⁶ This cost function has the form:

$$\ln C = \ln \alpha_0 + \alpha_a \ln Q + \sum_i \alpha_i \ln P_i + \frac{1}{2} \gamma_{aa} (\ln Q)^2 + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \sum_i \gamma_{ia} \ln Q \ln P_i \quad (4)$$

where $i, j = K, L, E$ and M .

From Shephard's Lemma, the input demand functions are derived by differentiating the cost function in Eq.(4) with respect to the input prices. The cost-minimizing quantity demanded of the i th input is $X_i = \partial C / \partial P_i$ and

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{\partial C}{\partial P_i} \frac{P_i}{C} = \frac{P_i X_i}{C} = S_i \quad (5)$$

where S_i is the relative share of the i th input in total cost. The input demand function in terms of cost shares is then:

$$S_i = \alpha_i + \gamma_{aa} \ln Q + \sum_j \gamma_{ij} \ln P_j \quad (6)$$

where $i, j = K, L, E$ and M .

In order to correspond to a well-behaved production function, the cost function must be homogenous of degree 1 in input prices. That is, for a fixed level of output, total expenditure must increase proportionately when all input prices

⁶A cost function is non-homothetic if factor shares are dependent on total output, and this implies that the output elasticity of each factor is different and varies from unity [80].

increase in the same proportion. ⁷ Christensen, Jorgenson and Lau [18] show that this implies that the following parameter restrictions must be imposed:

$$\begin{aligned}
 \sum_i \alpha_i &= 1, & \alpha_i &> 0 \\
 \sum_i \gamma_{ia} &= 0 \\
 \gamma_{ij} &= \gamma_{ji} \\
 \sum_j \gamma_{ij} &= \sum_i \gamma_{ji} = 0
 \end{aligned}
 \tag{7}$$

where $i, j = K, L, E$ and M and $i=j$.

The cost function specified in Eq.(4) is non-homothetic and may have non-constant returns to scale. The cost function would be homothetic if it could be written as a separable function of output and factor prices. Thus the additional parameter restrictions $\gamma_{ia} = 0$ can be added to impose homotheticity.

The cost function is also homogenous of degree 1 in Q if the elasticity of cost with respect to output is constant; this implies the additional restriction that $\gamma_{aa} = 0$.⁸

⁷There are additional conditions relating to concavity which are usually checked after estimation.

⁸These restrictions are tested by the F-test, discussed latter.

on page 63

The following set of share equations can be derived from the cost function in Eq.(4):⁹

$$\begin{aligned} S_K &= \alpha_K + \gamma_{KQ} \ln Q + \gamma_{KK} \ln P_K + \gamma_{KL} \ln P_L + \gamma_{KE} \ln P_E \\ S_L &= \alpha_L + \gamma_{LQ} \ln Q + \gamma_{LK} \ln P_K + \gamma_{LL} \ln P_L + \gamma_{LE} \ln P_E \\ S_E &= \alpha_E + \gamma_{EQ} \ln Q + \gamma_{EK} \ln P_K + \gamma_{EL} \ln P_L + \gamma_{EE} \ln P_E \end{aligned} \quad (8)$$

where total cost, $C = P_K K + P_L L + P_E E$.

Estimates of the own and cross price elasticities of demand are calculated from the estimated cost shares in Eqs.(8). The own price elasticity of demand for input 'i' is:

$$\eta_{ii} = \frac{\partial X_i}{\partial P_i} \frac{P_i}{X_i} = P_i \frac{\partial X_i}{\partial P_i} / X_i \quad (9)$$

By Shephard's Lemma, $X_i = \partial C / \partial P_i$ (10)

and $\frac{\partial X_i}{\partial P_i} = \frac{\partial^2 C}{\partial P_i^2}$ (11)

Substituting Eq.(11) into Eq.(9):

$$\eta_{ii} = P_i \frac{\partial^2 C}{\partial P_i^2} / X_i \quad (12)$$

⁹ Due to the absence of data on prices and quantities of materials, the share equation of material is not included in the estimation.

From Eq.(5), $X_i = S_i \frac{C}{P_i}$.

Substituting the value of X_i into Eq.(11):

$$\frac{\partial^2 C}{\partial P_i^2} = \frac{\partial}{\partial P_i} (X_i) = \frac{\partial}{\partial P_i} \left(S_i \frac{C}{P_i} \right)$$

Or
$$\frac{\partial^2 C}{\partial P_i^2} = \frac{P_i \left(C \frac{\partial S_i}{\partial P_i} + S_i \frac{\partial C}{\partial P_i} \right) - S_i C}{P_i^2} \quad (13)$$

From Eq.(8), $\frac{\partial S_i}{\partial P_i} = \gamma_{ii} \frac{1}{P_i}$. From Eq.(10), $\frac{\partial C}{\partial P_i} = X_i$.

Substituting these values into Eq.(13):

$$\frac{\partial^2 C}{\partial P_i^2} = \frac{1}{P_i^2} \left(C \gamma_{ii} + P_i S_i X_i - S_i C \right) \quad (14)$$

Substituting Eq.(14) for $\frac{\partial X_i}{\partial P_i}$ and Eq.(5) for X_i into Eq.(9):

$$\eta_{ii} = P_i \left[\frac{C}{P_i^2} \left\{ \gamma_{ii} + \frac{P_i}{C} S_i \left(\frac{S_i C}{P_i} \right) - S_i \right\} \right] / \frac{S_i C}{P}$$

Or
$$\eta_{ii} = \frac{\gamma_{ii} + S_i^2 - S_i}{S_i} \quad (15)$$

Similarly, the cross price elasticity of demand for input 'i' with respect to the price of input 'j' is:

$$\eta_{ij} = \frac{\partial X_i}{\partial P_j} \frac{P_j}{X_i} = P_j \frac{\partial X_i}{\partial P_j} / X_i \quad (16)$$

By Shephard's Lemma, $X_i = \partial C / \partial P_i$

and
$$\frac{\partial X_i}{\partial P_j} = \frac{\partial^2 C}{\partial P_i \partial P_j} \quad (17)$$

Substituting Eq.(17) into Eq.(16):

$$\eta_{ij} = P_j \frac{\partial^2 C}{\partial P_i \partial P_j} / X_i \quad (18)$$

where

$$\frac{\partial^2 c}{\partial P_i \partial P_j} = \frac{\partial}{\partial P_j} \left(\frac{S_i c}{P_i} \right) = \frac{c \gamma_{ij}}{P_i P_j} + \frac{S_i S_j c}{P_i P_j} \quad (19)$$

Substituting Eqs. (5) and (19) into Eq. (18):

$$\eta_{ij} = P_j c \left(\frac{\gamma_{ij}}{P_i P_j} + \frac{S_i S_j}{P_i P_j} \right) / \frac{S_i c}{P_i}$$

$$\text{Or } \eta_{ij} = \frac{P_i P_j c}{P_i P_j} (\gamma_{ij} + S_i S_j) / S_i c$$

$$\text{Or } \eta_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i} \quad (20)$$

The elasticity of substitution of a factor is tied intimately to its own price elasticity and the elasticities of alternative factors.

Uzawa [91] showed that the Allen Elasticity of Substitution (AES), σ_{ij} can be computed by the formula: ¹⁰

$$\sigma_{ij} = \frac{c (\partial^2 c / \partial P_i \partial P_j)}{(\partial c / \partial P_i) (\partial c / \partial P_j)} \quad (21)$$

¹⁰The AES is the proportional change in the ratio of two factors resulting from a unit proportional change in their relative prices. Thus an elasticity of substitution of 1 for capital and labour implies that 1 percent increase in the price ratio P_L/P_K results in a 1 percent increase in the factor ratio, K/L . If the AES between two factors is positive, we call the factors (AES) substitutes, while if the elasticity is negative, the factors are (AES) complements [54].

Substituting Eqs.(10) and (17) into Eq.(21):

$$\sigma_{ij} = \frac{c \left(\frac{\partial X_i}{\partial P_j} \right)}{X_i X_j} \quad (22)$$

Multiplying and dividing Eq.(22) by P_j :

$$\sigma_{ij} = \frac{c}{P_j X_j} \left(\frac{\partial X_i}{\partial P_j} \right) \frac{P_j}{X_i} \quad (23)$$

$$\text{Or} \quad \sigma_{ij} = \frac{1}{S_j} \eta_{ij} \quad (24)$$

$$\text{Or} \quad \sigma_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i S_j} \quad (25)$$

$$\text{Or} \quad \eta_{ij} = S_j \sigma_{ij} \quad (26)$$

Similarly, ''

$$\sigma_{ii} = \frac{1}{S_i} \eta_{ii} \quad (27)$$

$$\text{Or} \quad \sigma_{ii} = \frac{\gamma_{ii} + S_i^2 + S_i}{S_i^2} \quad (28)$$

$$\text{Or} \quad \eta_{ii} = S_i \sigma_{ii} \quad (29)$$

 ''Note that σ_{ii} does not have an economic meaning. It can be used conveniently to compute the value of η_{ii} . By the parameter estimates of share equations, we get the value of γ_{ii} , as given in Eq.(28). The value of σ_{ii} is then used to estimate the value of the own-price elasticity, η_{ii} as given in Eq.(27).

It is important to understand clearly the meaning of AES. It is a measure of relative substitution between two factors compared with the substitution effects of other factors. Take three factors, capital, labour, and energy, as an example. For a fixed amount of output, two inputs (say capital and energy) taken by themselves are always substitutes [32]. However, an increase in the price of energy, while leading to the substitution by capital, might result (with a decrease in output) in (a) greater substitution of labour, (b) decrease in the use of capital and energy together and, (c) net decrease in the use of capital [80]. Thus if a substitution between capital and energy is small relative to the substitution of their composite with labour, capital and energy are AES complements or in Berndt and Wood's terminology, they are 'net complements'. If, on the other hand, the substitution between capital and energy is large relative to the substitution of their composite with labour, then capital and energy are AES substitutes or 'net substitutes'.

The assumption of linear homogeneity in factor prices together with the symmetry restriction ensures that parameter estimates of any two equations exactly identify all parameters of the three equation system (8). For example, the restriction that $\alpha_K + \alpha_L + \alpha_E = 1$ ensures that $\hat{\alpha}_E = 1 - \hat{\alpha}_K - \hat{\alpha}_L$. Similarly the symmetry restriction ensures that $\hat{\gamma}_{ij} = \hat{\gamma}_{ji}$, $i \neq j$. Finally, the restriction of zero row sums of the γ 's requires that $\hat{\gamma}_{ij} = -(\hat{\gamma}_{ii} + \hat{\gamma}_{is})$ for $i, j, s = K, L$ and E .

The parameters of the share equations can be estimated by ordinary least squares. However, this would neglect the additional information contained in each share equation. Furthermore, factor prices which appear as regressors in the equation have a tendency to move together over time. Hence multicollinearity may be a problem resulting in imprecise parameter estimates.

An alternative estimation procedure is to estimate jointly the cost share equations as a multiequation regression system. This procedure is more satisfactory, since the cost-share equations include all parameters, except the constant, in the price possibility frontier. No information is lost by not including the price possibility frontier in the estimation procedure.

Since the system of equations has cross-equation parameter constraints, these equations should be estimated under the assumption of a stochastic specification where the error terms are heteroscedastic, autocorrelated over time and correlated across equations in the system. However, estimating such a specification (which amounts to a full generalized least squares) would be unreasonably costly even if individual equations were linear in the parameters.

Therefore, we will settle for a more restrictive and simpler stochastic specification.¹² We ignore the error term

¹² This is supported on the ground that the use of additive error terms in the share equations is fairly arbitrary. The cost-share equations are derived by differentiation, they do not contain the disturbance term from the cost function.

heteroscedasticity and autocorrelation within equations, and account only for error correlations across equations. Then, we use the iterative Zellner estimation technique. We delete one of the share equations from the system. Otherwise the estimated disturbance covariance matrix required to implement Zellner's procedure becomes singular, because the disturbances in the share equations must sum up to zero.

Barten [6] has shown that maximum likelihood estimates of a system of share equations with one equation deleted are invariant to which equation is dropped. Kmenta and Gilbert [50] have shown that iteration of the Zellner estimation procedure until convergence results is equivalent to a maximum likelihood estimation. Iterating the Zellner procedure is a computationally efficient method for obtaining the maximum likelihood estimates, and it is the procedure employed here.¹³

2. Data

The share equations are estimated with pooled annual data on prices and quantities of capital, labour and energy, compiled by the Census of Manufacturing Industries (CMI). CMI is published irregularly. CMI data are available only for five years during 1960 to 1970. These years are 1959-60, 1962-63,

¹³All of the estimation work in the study has been carried out using the GREMLIN experimental nonlinear estimation package, which is part of the TROLL econometric software system.

1964-65, 1966-67 and 1969-70. However, in a project financed by the Planning Commission of Pakistan, A.R. Kemal [46;47] has prepared consistent time-series data for sixteen large-scale manufacturing industries in Pakistan for the years 1959-60 to 1969-70. ¹⁴ For estimation of share equations, pooled data -- cross-section of sixteen industries for the time-series of eleven years -- by Kemal is used.

The share of a factor is defined as the value (product of quantity and price) of a factor divided by the total cost. The total cost is the sum of the cost of fuel and electricity, total wage bill and the corrected written down replacement cost of fixed assets, explained below.

Disaggregate data on the consumption of energy -- amount of fuel and electricity -- by industries are not available. It is estimated by dividing the cost on fuel and electricity by the price of energy. ¹⁵ The cost of fuel and electricity is not given by Kemal. He calculates the industrial cost that includes costs incurred for raw materials, fuel and electricity. The cost of fuel and electricity is constructed by using the CMI data for

¹⁴Energy price has increased tremendously since 1973. It would be more appropriate to estimate the price elasticity of energy demand and elasticities of substitution between energy and other factors for 1970s. Although CSO has published CMI data for 1972-73, 1975-76 and 1977-78, consistent time series data have not been prepared for these years. This precluded us from extending the present study to the 1970s.

¹⁵Except for power, cement and fertilizer industries, not included in the estimation, the prices of fuels were same for all other industries [72].

the years specified above.¹⁶ First, the percentage of cost of fuel and electricity in the industrial cost, reported in the CMI data is calculated. This percentage is then used to estimate the percentage of cost of fuel and electricity in the industrial cost, estimated by Kemal to get consistent data for the estimation period.

Capital is the corrected written down replacement cost of fixed assets including depreciation, taken from Kemal [47]. Labour is represented by figures on employment of skilled and unskilled labour. The price of labour (wage) is calculated by dividing the total wage bill by total employment. Data for the wage bill and employment are obtained from [46]. The price of energy is a weighted average of the prices of coal, electricity, natural gas and petroleum products for the manufacturing sector of Pakistan. Data for the prices of fuels are taken from [70;72].

The value of output is the value of the gross product minus the cost of material. The cost of material is estimated by subtracting the cost of fuel and electricity from industrial cost. The value of output is also taken from [46].

The value of output and prices of energy and labour are expressed as indices. The price index of capital is taken from [47].¹⁷

¹⁶For missing years of CMI data, the cost of fuel and electricity is estimated by the inter- and extra-polation.

¹⁷The price indices for capital goods are obtained by constructing a weighted price index using wholesale price indices of machinery, transport equipment and buildings. The

These variables are expressed as indices for estimating share equations.

Before interpreting the results of elasticities derived from estimates of the share equations, it would be appropriate to explain some of the statistical techniques employed in this study. Elasticity estimates are useful when they are accompanied by the standard errors. A problem in calculating standard errors for our estimates of elasticities is that the elasticities are nonlinear functions of the estimated parameters, since the shares are themselves functions of the parameters. Thus there is no straightforward way to calculate the exact variances of elasticities without reverting to Monte Carlo simulation. However, approximate estimates can be obtained on the standard errors under the assumption that the shares, S_i , are constant and equal to the means over the estimation time bounds of their estimated values. Under these assumptions we have asymptotically, [80]

$$\begin{aligned}
 \sqrt{\text{var}(\hat{\sigma}_{ij})} &= \sqrt{\text{var}(\hat{\gamma}_{ij}) / \hat{S}_i^2 \hat{S}_j^2} \\
 \sqrt{\text{var}(\hat{\sigma}_{ii})} &= \sqrt{\text{var}(\hat{\gamma}_{ii}) / \hat{S}_i^4} \\
 \sqrt{\text{var}(\hat{\eta}_{ij})} &= \sqrt{\text{var}(\hat{\gamma}_{ij}) / \hat{S}_i^2} \\
 \sqrt{\text{var}(\hat{\eta}_{ii})} &= \sqrt{\text{var}(\hat{\gamma}_{ii}) / \hat{S}_i^2}
 \end{aligned}
 \tag{30}$$

¹⁷(cont'd) weights of the three components are taken from [34]. Since no price index for buildings was available, this was constructed using price indices of cement, steel and bricks. The weights were taken from [88].

Industrial homogeneity and homotheticity of cost functions are tested by an F-statistic. The F-statistic is calculated by the change in the weighted Sum of Squared Residuals (SSR) with restrictions and without restrictions divided by the number of restrictions.¹⁸ This ratio is then divided by the ratio of the weighted sum of squared residuals without restrictions to the number of residual degrees of freedom.¹⁹ The resulting test statistic is distributed asymptotically as $F(\nu_1, \nu_2)$ where ν_1 is the number of restrictions and ν_2 is the number of residual degrees of freedom. Each F-statistic is distributed asymptotically as Chi-squared divided by its degrees of freedom (restrictions imposed). These test statistics are asymptotically equivalent to the likelihood-ratio test statistics [16].

3. Results on Factor Substitution

Different versions of the model were estimated. Only two of these are reported in Table III-1. Standard errors are given in parentheses. In each version, pooled data of a cross-section of sixteen manufacturing industries and a time-series of eleven observations (years) are used. In the first version, not reported here, the model is restricted to be homogenous in the

¹⁸ There are three equations in the system. SSR, is therefore, a weighted average of the SSRs of the three equations.

¹⁹The degrees of freedom is the total number of observations used in the three equations minus the number of parameters estimated.

Table III - 1

Parameter Estimates of Factor-Share
Model of All Industries Pooled in Pakistan*

	<u>Non-Homothetic</u>	<u>Homothetic</u>
α_L	= -0.7204 (0.165)**	-0.6661 (0.110)
α_K	= 1.8407 (0.211)	2.1230 (0.143)
α_E	= -0.1204 (0.090)	-0.4572 (0.064)
γ_{QL}	= -0.0026 (0.000)	
γ_{QK}	= -0.0129 (0.006)	
γ_{QE}	= 0.0155 (0.003)	
γ_{LL}	= -0.0633 (0.000)	-0.0521 (0.033)
γ_{KK}	= -0.1284 (0.055)	-0.1091 (0.028)
γ_{EE}	= 0.0213 (0.008)	0.0066 (0.004)
γ_{LK}	= 0.1065 (0.032)	0.0839 (0.023)
γ_{LE}	= -0.0432 (0.034)	-0.0318 (0.020)
γ_{KE}	= 0.0219 (0.012)	0.0252 (0.011)
<u>Equations:</u>	<u>R²</u>	<u>R²</u>
Labour	0.88	0.88
Capital	0.79	0.80
Energy	0.75	0.78

* The estimates on dummy coefficients are not reported here.

** Figures in parantheses from Table III - 1 to Table III - 6 are Standard Errors.

industrial structure, i.e. no intercept dummy variables were included to allow for different structures for the industries. The restriction of industrial homogeneity is tested by comparing the equivalent unrestricted model, where 15 dummy variables were included to capture the differences in the cost structure of the 16 industries. The value of the F-statistic is 4.87 and given that there are 45 parameter restrictions, this is well above the critical value at the 5% level with (45,468) d.f.²⁰ Therefore, 15 dummies in each equation are included.²¹ The estimates of the model parameters are given in column 1 of Table III-1.

The restriction of homotheticity is then imposed on the cost function, i.e. $\gamma_{i\alpha} = 0$, $i = K, L, E$. The results are given in Column 2 of Table III-1. Homotheticity is tested by an F-test. The value of the F-statistic is 4.02.²²

²⁰ 15 dummies times 3 equations.

²¹ Dummy variables for each industry can also be used to allow for second-order parameters to vary across industries. However, this method reduces the degrees of freedom considerably and results in large standard errors of elasticities. Therefore, the dummy variables for each industry were used only for the intercept terms.

²² The value of the change in the weighted SSR with and without restrictions divided by the number of restrictions is 0.00342, and the value of the ratio of SSR without restrictions to degrees of freedom is 0.000849. The ratio of the two is 4.02.

This is significant at the 5% level with (3,468) d.f., implying that homotheticity can not be accepted. ²³

All parameter estimates for the share equations in Table I are statistically significant except for γ_{EL} . The R-squares for all equations are high, but a good deal of this explanation can be attributed to the industries' dummy variables.

To obtain elasticities for sixteen industries separately, the share equations for each industry are estimated by using the time-series data for 1960 to 1970. The parameter estimates of the share equations of the individual industries were statistically insignificant, probably due to the small number of observations. In order to increase the degrees of freedom, sixteen industries were pooled into different sets. Each set consisted of three industries, except one, which had four industries. ²⁴ The inclusion of industries in each set was decided on the basis of closeness of their parameter estimates (obtained by OLS) and factor shares in total cost. These results are reported in Table III-2. Most of the parameter estimates of the share equations of all sets are statistically significant.

²³However, to get consistent estimates of elasticities of substitution and own and cross price elasticities of all sixteen industries pooled and each industry separately, results obtained by the restricted homothetic model are used. The cost functions of individual industries are found to be homothetic in structure.

²⁴Paper, Machinery and Metal Products are placed in the first set; Textiles, Food and Basic Metals in the second set; Rubber, Chemical and Electrical Machinery in the third set; Transport, Tobacco and Non-Metallic Products in the fourth set; and Leather, Footwear, Printing and Miscellaneous industries in the last set.

Table III - 2

Parameter Estimates of Factor-Share Model
of Sets of Industries Pooled in Pakistan

	(1)	(2)	(3)	(4)	(5)
α_L	-0.9589 (0.176)	0.2894 (0.245)	0.2298 (0.508)	-0.7108 (0.330)	-0.6146 (0.265)
α_K	2.2260 (0.236)	0.7869 (0.436)	1.1839 (0.546)	1.5869 (0.191)	1.8041 (0.346)
α_E	-0.2671 (0.236)	-0.0763 (0.194)	-0.4137 (0.146)	0.1239 (0.279)	-0.1894 (0.099)
γ_{LL}	-0.1973 (0.165)	0.0313 (0.013)	0.0646 (0.040)	0.0389 (0.025)	0.0868 (0.047)
γ_{KK}	-0.0306 (0.020)	0.3393 (0.182)	0.0622 (0.026)	0.0052 (0.002)	0.1257 (0.053)
γ_{EE}	0.0471 (0.012)	0.3220 (0.313)	0.0266 (0.015)	0.0015 (0.001)	0.0021 (0.001)
γ_{LK}	0.1375 (0.043)	-0.1692 (0.068)	-0.0501 (0.025)	-0.0213 (0.014)	-0.1052 (0.053)
γ_{LE}	0.0598 (0.038)	0.1379 (0.037)	-0.0145 (0.008)	-0.0176 (0.011)	0.0184 (0.012)
γ_{KE}	-0.1069 (0.030)	-0.1701 (0.064)	-0.0121 (0.006)	0.0161 (0.008)	-0.0205 (0.014)
Equations: $\underline{R^2}$		$\underline{R^2}$	$\underline{R^2}$	$\underline{R^2}$	$\underline{R^2}$
Labour	0.96	0.75	0.88	0.92	0.81
Capital	0.93	0.74	0.78	0.99	0.72
Energy	0.67	0.69	0.90	0.98	0.52

Note:

Paper, Machinery and Metal Products are placed in the first set; Textiles, Food and Basic Metals in the second set; Rubber, Chemical and Electrical Machinery in the third set; Transport, Tobacco and Non-Metallic Products in the fourth set; and Leather, Footwear, Printing and Miscellaneous industries in the last set.

γ_{LL} in the first and the third sets, γ_{KK} in the first and the fifth sets and γ_{EE} in the second and the fourth sets are statistically insignificant at the 5% level.

The tests for homogeneity and homotheticity were carried out for each set of industries. The F-test showed that industrial homogeneity for each set of industries was not acceptable, while the test for homotheticity of cost functions for each set of industries was acceptable. Therefore, two dummy variables were included in the estimated share equations of the first four sets and three dummy variables in the last set to incorporate differences in the cost structure of each industry.

The resulting elasticities of substitution for capital, labour and energy are shown in Table III-3 for the model in which all sixteen industries are pooled together (row 1) and the model in which five sets of industries are pooled separately.²⁵ The standard errors of these elasticity estimates were constructed from the formula given in Eqs(29). All estimates of the industries pooled are significant, except for σ_{LE} and η_{LE} . Note that elasticities are reported for each individual industry. These elasticities are estimated by using the factor shares of each industry and the parameter estimates of Table III-2. Though the parameter estimates are the same for each industry belonging to a given set, factor shares of each industry are different. Therefore, different elasticity

²⁵ These results are obtained with the restriction that

Table III - 3

Elasticities of Substitution of Labour,
Capital and Energy in Manufacturing Sector of Pakistan

<u>Industries</u>	σ_{LL}	σ_{KK}	σ_{EE}	σ_{LK}	σ_{LE}	σ_{KE}
All Industries	-7.095 (1.245)	-0.447 (0.046)	-16.361 (1.800)	0.879 (0.180)	-0.498 (2.552)	1.641 (0.292)
Food	-5.674 (1.219)	0.292 (0.251)	40.256 (161.6)	-0.875 (0.754)	28.873 (7.991)	-3.545 (1.711)
Tobacco	-3.811 (1.027)	-0.226 (0.032)	-27.114 (0.951)	0.831 (0.110)	-2.318 (2.055)	1.580 (0.301)
Textiles	-5.398 (1.072)	0.280 (0.252)	61.621 (228.5)	-0.759 (0.707)	33.767 (8.540)	-4.405 (2.134)
Footwear	-1.216 (0.427)	-0.272 (0.217)	-24.493 (0.876)	0.499 (0.213)	2.488 (0.954)	0.119 (0.627)
Paper	-57.769 (37.94)	-0.221 (0.228)	-4.273 (1.521)	3.447 (0.770)	11.394 (6.782)	-0.453 (0.412)
Printing	-1.650 (0.814)	-0.123 (0.017)	-48.074 (3.703)	0.413 (0.217)	5.132 (2.708)	-0.539 (1.096)
Leather	-1.664 (0.835)	-0.154 (0.018)	-19.746 (0.567)	0.385 (0.007)	2.673 (1.071)	0.376 (0.443)
Rubber	-2.734 (1.511)	-0.147 (0.040)	-6.596 (11.46)	0.608 (0.195)	-1.464 (1.444)	0.593 (0.231)
Chemical	1.676 (10.40)	-0.073 (0.023)	-7.707 (2.814)	0.067 (0.466)	-2.203 (1.887)	0.808 (0.106)
Non-Metallic	-5.398 (4.720)	-0.235 (0.003)	-7.030 (0.727)	0.637 (0.231)	-0.893 (1.213)	1.162 (0.083)
Basic Metal	-4.380 (0.642)	0.262 (0.294)	13.396 (71.83)	-0.468 (0.591)	15.217 (3.870)	-2.268 (1.322)
Metal	-6.510 (2.880)	-0.466 (0.040)	-0.200 (4.401)	1.786 (0.253)	5.937 (3.221)	-1.981 (0.846)
Machinery	-9.443 (4.521)	-0.408 (0.037)	-3.620 (2.451)	1.970 (0.845)	5.476 (2.912)	-1.096 (0.590)
Electrical	-2.113 (0.736)	-0.228 (0.046)	13.698 (35.60)	0.712 (0.143)	-1.963 (1.737)	0.227 (0.427)
Transport	-4.180 (1.304)	-0.196 (0.003)	-30.666 (1.222)	0.815 (0.121)	-3.076 (2.613)	1.645 (0.332)
Miscellaneous	-1.314 (4.180)	-0.011 (0.025)	-17.454 (1.443)	-0.176 (0.597)	4.265 (2.111)	0.531 (0.333)

estimates of each industry can be obtained by using Eqs.(24) and (26).

Partial price elasticities of demand for the three factors are shown in Table III-4, again for the models in which (a) all sixteen industries are pooled and (b) five set of industries are separately pooled. The price elasticities are estimated from Eqs.(25) and (27).

Let us now consider the implications of these elasticity estimates. The elasticity of substitution for labour and capital is positive for manufacturing as a whole and for each industrial unit. This implies that labour and capital are substitutes in the manufacturing sector of Pakistan. For some industries like food, textiles, basic metal and miscellaneous industries, the elasticities of substitution have negative signs, but these are statistically insignificant. With the exception of paper, metal and machinery products, where the values of elasticities of substitution exceed unity, the values of the elasticities are lower than one for the other industries and all sixteen industries pooled. The elasticity estimates range from 0.50 for footwear to 0.87 for industries as a whole. Therefore, it can be said that although substitution possibilities exist between labour and capital in the manufacturing sector of Pakistan, the extent of substitution has been rather limited (0.87). This is due to the fact that machineries and techniques employed in the manufacturing sector are borrowed from the West. The western technologies are oriented to the needs of capital exporting

Table III - 4

Partial Price Elasticities of Demand for
Labour, Capital and Energy in Manufacturing Sector of Pakistan

<u>Industries</u>	η_{LL}	η_{KK}	η_{EE}	η_{LK}	η_{LE}	η_{KE}
All Industries	-1.156 (0.202)	-0.351 (0.036)	-0.818 (0.088)	0.044 (0.021)	-0.024 (0.127)	0.082 (0.014)
Food	-0.601 (0.129)	0.248 (0.214)	-1.601 (7.111)	-0.038 (0.080)	1.270 (0.847)	-0.155 (0.604)
Tobacco	-0.594 (0.160)	-0.183 (0.002)	-0.918 (0.032)	0.028 (0.017)	-0.078 (0.069)	0.053 (0.010)
Textiles	-0.609 (0.011)	0.238 (0.215)	2.257 (8.456)	-0.085 (0.081)	1.246 (0.330)	-0.162 (0.075)
Footwear	-0.406 (0.140)	-0.171 (0.085)	-0.906 (0.032)	0.166 (0.084)	0.092 (0.035)	0.004 (0.043)
Paper	-3.760 (2.561)	0.187 (0.240)	-0.367 (0.013)	0.227 (0.050)	0.979 (0.441)	-0.038 (0.035)
Printing	-0.399 (0.191)	-0.091 (0.011)	-0.864 (0.066)	0.099 (0.041)	0.092 (0.041)	-0.009 (0.018)
Leather	-0.397 (0.153)	-0.110 (0.017)	-0.908 (0.026)	0.092 (0.015)	0.122 (0.049)	0.017 (0.019)
Rubber	-0.434 (0.183)	-0.118 (0.030)	-0.244 (0.424)	0.096 (0.025)	-0.054 (0.050)	0.022 (0.007)
Chemical	0.103 (0.645)	-0.063 (0.028)	-0.562 (0.205)	0.004 (0.028)	-0.160 (0.116)	0.059 (0.007)
Non-Metallic	-0.394 (0.342)	-0.188 (0.003)	-0.861 (0.089)	0.046 (0.015)	-0.109 (0.088)	0.143 (0.013)
Basic Metal	-0.639 (0.089)	0.206 (0.231)	-0.883 (4.780)	-0.068 (0.086)	1.003 (0.255)	-0.149 (0.080)
Metal	-1.553 (0.691)	-0.331 (0.027)	-0.010 (0.220)	0.426 (0.055)	0.296 (0.158)	-0.099 (0.042)
Machinery	-1.803 (0.865)	-0.301 (0.025)	-0.249 (0.159)	0.376 (0.058)	0.377 (0.550)	-0.075 (0.040)
Electrical	-0.492 (0.171)	-0.170 (0.034)	0.287 (0.714)	0.165 (0.033)	-0.041 (0.034)	0.004 (0.008)
Transport	-0.581 (0.178)	-0.162 (0.026)	-0.919 (0.036)	0.113 (0.016)	-0.090 (0.071)	0.049 (0.009)
Miscellaneous	-0.139 (0.441)	-0.009 (0.062)	-0.907 (0.023)	-0.018 (0.062)	0.221 (0.103)	0.027 (0.016)

countries and do not permit much substitution between capital and labour [19].

Similar results are derived by Kemal for Pakistan [48] and Diwan and Gujrati for India [23]. However, Kemal's study is not very reliable as the values of elasticities and their level of significance vary greatly from the CES production function to the VES production function -- the two models used for the estimation of the elasticities of substitution. Further, more than half of the elasticity estimates are statistically insignificant in both versions of the model. Interestingly, those industries which are statistically significant in the CES model turn out to be statistically insignificant in the VES model and vice versa.

The elasticity of substitution between energy and capital is negligible in magnitude and statistically insignificant at the 5% level. However, from the signs of the elasticity estimates, capital and energy may be identified as substitutes in the manufacturing sector of Pakistan. Unfortunately, other studies on substitution elasticities between energy and other factors are not available for Pakistan. Williams and Lumas [94] have estimated the elasticities of substitution between capital, labour, energy and other factors for India by using translog cost functions. Their results show that all factors are substitutes in relation to each other. For some industries, energy appears as a complement to labour, but statistically these estimates are insignificant. In general, the values of

elasticities are close to the estimates, obtained in this study. Similar studies in the developed countries show that capital and energy are substitutes. See for example, Pindyck [79;80] and Griffin and Gregory [33]. However, Berndt and Wood [10] and Fuss [29] found a strong complementary relationship between capital and energy. It is pointed out by Pindyck that Berndt and others have worked with time series data and perhaps estimated the short-run cost or production functions, whereas his study was based on pooled data on a cross-section of developed countries. Note that Pindyck's estimates and the results obtained in this study are the long-run elasticities. Most of the variation in factor shares data is cross-sectional rather than time-series.

The elasticities of substitution for energy and labour have mixed signs, and most of these estimates are statistically insignificant. The estimates which are statistically significant show that energy and labour are substitutes, though their magnitudes are very small.

The own-price elasticity of capital ranges from -0.063 in the chemical industry to -0.331 for the metal industry. The demand for capital is more inelastic in the chemical industry because labour and energy are poor substitutes for capital. As a whole, the own-price elasticity of capital is around -0.35, implying that capital is price inelastic in the manufacturing sector of Pakistan. This reflects an almost general phenomenon in underdeveloped countries faced by capital deficiency.

The divergence in the elasticity estimates for different industries are due to the differences in the factor share composition and values of the parameter estimates of the share equations of each industry.

The own-price elasticity of capital estimates for India are relatively higher than the estimates of this study [94]. This may be due to differences in methodology between the two studies. First, this study is pooled for 16 industries using 11 years of observations. The Indian study is based on cross-sectional data for 8 large scale manufacturing industries for the year 1968. Secondly, the partial price elasticities have been estimated, while for India total price elasticities are reported. The total elasticity would be larger than the partial elasticities, since they account for changes in the use of energy as well as interfuel substitution. There is no data available to estimate the interfuel substitution for each industry.

The estimates for the own-price elasticity of labour are also relatively smaller than the estimates for India. The own-price elasticity of demand for energy is higher than those for labour and capital in India and Pakistan. It is assumed that the capital stocks are relatively less energy-intensive in underdeveloped countries. Therefore, it would be easier to adjust the total capital stock composition to changes in the price of energy. As a result, energy demand would be price elastic. The elasticity estimates obtained for the developed

countries are relatively higher in values. This implies that factors are more responsive to changes in their prices in developed countries. ²⁶

The values of the cross-price elasticities for capital and labour, energy and capital, and energy and labour are very small in Pakistan. These factors can be described as mostly substitutes from the signs of their elasticity estimates. For some industries, energy appears as a complement with capital and labour, but these estimates are statistically insignificant. The cross-price elasticities are not available for India. However, input pairs look like substitutes in India from the estimates of their elasticities of substitution. For some industries, labour and energy are complements in India, but their low level of significance make these estimates unreliable. The cross-price elasticities estimated for the developed countries are relatively higher in value and indicate a substitute in relationship [79;80].

4. Results on Interfuel Substitution

For estimating the elasticities of interfuel substitution, we need data on different types of fuels consumed in the industry. Such data are unavailable for each industry. However, time series data from 1960 to 1981 are available for natural

²⁶ See, for example, Pindyck [79;80].

gas, electricity, furnace oil and coal for the industrial sector as a whole. These fuels together account for 98% of the total commercial energy consumed in the industry [70]. For these years, substitution between natural gas, electricity, furnace oil and coal are estimated using the iterative Zellner method²⁷.

Parameter estimates of fuel share equations are given in Table III-5. Parameters of all fuel shares, except coal are significant statistically. The percentage share of coal in the total cost of fuels in industry declined sharply from 36% in 1960 to 11% in 1981 [70]. This was mainly due to the adequate supply of more efficient fuels, like natural gas, at relatively low prices.

The elasticities of interfuel substitution and (partial) own and cross price elasticities of these fuels are given in Table III-6. The wide variations in elasticities of substitution and concurrently in price elasticities of fuels are due to differences in the share composition of each fuel. For example, electricity has the highest cost share (50%), and as a result, its demand is price inelastic. Furnace oil, on the other hand, has a very low cost share (6%) and therefore, it has a high

²⁷The cost share equations of natural gas, electricity, furnace oil and coal are derived from the translog cost model, given in the section on methodology. Three share equations for natural gas, electricity and furnace oil are estimated. The share equation of coal is derived from the parameter estimates of the above three equations. Error term heteroscedasticity and autocorrelation within equations are ignored. Error correlations across equations is taken into account.

Table III - 5

Parameter Estimates of Fuel-Share Model
in Manufacturing Sector of Pakistan

α_N	1.391 (0.076)
α_E	0.654 (0.146)
α_C	-0.766 (0.188)
α_F	-0.279 (0.031)
γ_{NN}	0.008 (0.002)
γ_{EE}	0.161 (0.049)
γ_{CC}	0.062 (0.079)
γ_{FF}	-0.189 (0.073)
γ_{NE}	-0.167 (0.042)
γ_{NC}	0.011 (0.075)
γ_{NF}	0.164 (0.035)
γ_{EC}	-0.046 (0.064)
γ_{EF}	0.052 (0.017)
γ_{CF}	-0.027 (0.135)

<u>Equations</u>	<u>R²</u>
Natural Gas	0.95
Electricity	0.62
Coal	0.63
Furnace Oil	0.85

Note: N = Natural Gas
E = Electricity
C = Coal
F = Furnace Oil

Table III - 6

Elasticities of Substitution and Partial Price
Elasticities of Demand for Fuels in Manufacturing Sector of Pakistan

σ_{NN}	-0.882 (0.038)	η_{NN}	-0.200 (0.009)
σ_{EE}	-0.346 (0.167)	η_{EE}	-0.175 (0.086)
σ_{CC}	-2.432 (1.936)	η_{CC}	-0.490 (0.395)
σ_{FF}	-23.940 (18.39)	η_{FF}	-1.449 (1.158)
σ_{NE}	-0.451 (0.271)	η_{NE}	-0.225 (0.081)
σ_{NC}	1.239 (1.651)	η_{NC}	0.247 (0.340)
σ_{NF}	12.467 (2.447)	η_{NF}	0.748 (0.159)
σ_{EC}	0.551 (0.631)	η_{EC}	0.121 (0.128)
σ_{EF}	2.628 (0.532)	η_{EF}	0.157 (0.034)
σ_{CF}	-1.121 (10.608)	η_{CF}	-0.070 (2.076)

own-price elasticity of demand. The sign of the own-price elasticity of each fuel is consistent with theory. The positive signs of the cross-price elasticities between natural gas and furnace oil, natural gas and coal, and electricity and furnace oil, indicate that these fuels are substitutes. The relationship between natural gas and electricity, and between furnace oil and coal is complementarity. However, furnace oil and coal, as complements, are statistically not significant.

These results on interfuel substitution are consistent with the studies done for India and Western countries. Uri [89], using the pooled data on five commercial sectors from 1960 to 1971 and employing the translog cost model, estimated an own-price elasticity of -0.14 for electricity, -0.09 for oil and -0.15 for coal in the manufacturing sector of India. The cross-price elasticities of these fuels are positive in sign, and the values of these elasticities range from 0.09 to 0.16. Standard errors of these estimates are not reported. Applying the translog cost model to pooled data on the manufacturing sectors of North America, European countries and Japan, Pindyck [79] reported that the own-price elasticities of these countries range from -0.07 to -0.16 for electricity, -0.11 to -0.30 for oil, -0.30 to -2.31 for gas and -1.04 to -2.08 for coal. The values of cross-price elasticities between gas and electricity range from -0.15 to -1.82, between gas and coal from 1.35 to 2.21 and between electricity and oil from -0.03 to 0.28.

In general, these estimates of interfuel substitution are relatively higher than the results obtained in this study. These results are estimated from pooled data. We have relied on the time series data, which due to the reasons of "simultaneity between inputs and their prices and the dominance of cyclical conditions, e.g. under utilization of capacity," noted by Gaude [31], impart a downward bias to substitution elasticities.

IV. DEMAND FOR ENERGY IN THE TRANSPORTATION SECTOR

There is a considerable problem in constructing a model of total demand for petroleum products that incorporates all the varieties of petroleum products used in the different modes of transportation. There is little interfuel substitution within the different modes of transportation. Each mode uses a specific kind of fuel.¹ For instance, only jet and aviation fuels are used by the air lines; motor spirit is used in private automobiles; and diesel oil is the main fuel in public transportation. Further, the determinants of demand for petroleum products by the different transportation modes are different. Fuel consumption of railroads depends on freight-ton miles, passenger-ton miles, average speed of trains, length of the train and the distances between stops [61]. Fuel consumption of marine vessels is determined by the domestic and international cargo loaded/unloaded, passenger ton-miles travelled and average size of vessels [61]. Fuel consumption of buses and public commuters depends on the density of intercity traffic, the number of trips and load factors. For trucks, the determinants of fuel consumption are vehicle miles travelled and

¹Note that some portion of energy in the transportation sector is consumed by the government, defence, foreign air lines and bunkers. These demands can not be identified in the petroleum usage data. This may affect the parameter estimates of this study.

the freight-ton miles carried [61]. The demand for jet fuel for air line services depends on the passenger and cargo weight (load factor), number of take-offs and landings, the speed of the flight and the size of planes [25].

In this study, the transportation sector in terms of its mode of operation and fuel-use is divided into three sections. The demand for motor fuel by automobiles is analyzed in section I, the demand for aviation fuel by air planes in section II and demand for fuels by all other modes of transportation in section III.

There are several reasons for this division. First, the theory of demand for fuel by private automobiles can be illustrated by a dynamic flow-adjustment model, similar to the model of residential demand. Although, for practical purposes, the resulting equation of this model is also used for estimating the demand equations of other modes of transportation, such an application lacks theoretical justification.

Second, time-series data for gasoline demand for automobiles and aviation fuel by air planes are available in Pakistan. Separate data for fuel consumed by other modes like buses, trucks, railways and ships are not available.

Finally, buses and trucks use diesel oil with a mix of motor spirit. Similarly, railways use furnace oil together with coal and electricity. It is difficult to determine the fuel-mix of each mode independently [61].

For these reasons, fuels consumed by buses, trucks, railways and ships are analyzed jointly. A simple dynamic logarithmic model is used to estimate the demand for fuel in these modes of transportation. It has been empirically observed that a simple model often yields robust estimates of demand elasticities [80].

1. Model of Gasoline Demand

Gasoline is demanded by private automobiles (such as cars and motor cycles) and public automobiles (such as taxis, three-wheelers or motor rickshaws) in Pakistan. The demand for gasoline by both private and public users of automobiles depends on the stock, fuel-efficiency and the rate of utilization of automobiles. The stock of automobiles is determined by investment in new vehicles and the rate of depreciation.² The rate of utilization of automobiles depends on income and the price of gasoline. Fuel efficiency of automobiles responds to changes in the price of gasoline, but only with a long lag [60].

The breakdown of the number of automobiles in private and public uses is available for Pakistan. Data on automobile vintage, models, fuel-efficiency, price and the rate of utilization for each use are unavailable. Segregated data on

²Stock is not sensitive in the short-run to changes in prices of automobiles, the price of gasoline or income [60].

gasoline demand by private and public automobile owners are also not available. Therefore, gasoline demand in Pakistan will be estimated jointly for the two uses using an aggregate dynamic flow-adjustment model, commonly used in the developed countries, and similar to the model developed in chapter II.

Assume that the desired demand of gasoline by an individual, in period t , G_t^* is a function of his income, Y_t and price of gasoline, P_t [41;60].³

$$G_t^* = f(Y_t, P_t) \quad (1)$$

Assume that $f(\)$ is log-linear, so that⁴

$$g_t^* = \alpha + \beta y_t + \gamma p_t + u_t \quad (2)$$

where u_t is the error term in the log form.

Eq.(2) cannot be estimated because the desired quantity of gasoline demand is not observable. To replace it we assume that the 'actual' change in gasoline demand in any one period is only

³(1) Per capita consumption and per capita income are used as proxies for gasoline demand and income of a representative individual in Pakistan.

(2) Population and income are major determinants of mileage traveled or the gasoline used by automobiles. As population increases, vehicle miles tend to increase proportionately. As income increases, so do vehicle miles: people tend to engage in more activities requiring additional mobility. Fuel cost is another important variable determining the vehicle miles travelled. Fuel cost per mile of driving depends on the price of gasoline and the fuel efficiency of automobiles. The price of gasoline is the major element of variable cost in the short run. In the long run, fuel efficiency of engines increases due to technological advancement. This reduces the cost of fuel per mile traveled and increases vehicle miles driven [82].

⁴ See footnote 3 in chapter II.

a fraction of the 'desired' change. In logarithmic form, the adjustment process between the actual and the desired gasoline demand can be written as:

$$g_t - g_{t-1} = \phi (g_t^* - g_{t-1}) + v_t \quad (3)$$

where $0 < \phi \leq 1$ and v_t is the error term in logarithmic form.

Thus

$$g_t = \phi g_t^* + (1-\phi) g_{t-1} + v_t \quad (4)$$

Substituting Eq.(2) into Eq.(4):

$$g_t = \phi \alpha + \phi \beta y_t + \phi \gamma p_t + (1-\phi) g_{t-1} + \omega_t \quad (5)$$

where $\omega_t = \phi u_t + v_t$.

The estimation of Eq.(5) would yield short-run income and price elasticities in terms of the coefficients of income, $\phi \beta$ and price, $\phi \gamma$. The long-run demand elasticities can be derived by adjusting these coefficients with the partial adjustment coefficient, ϕ as shown in Eqs.(13) and (14) in chapter II.

2. Regression Results on Gasoline Demand

Generally OLS has been used to estimate the per capita fuel consumption equation in the different modes of transportation.⁵ The h-statistic shows that the error terms of the demand

⁵See chapter I, pp. 26-27 for the problems related with OLS estimation.

equations for gasoline and aviation fuels estimated by OLS are serially correlated at the 5% level of significance. The demand equations for these fuels are therefore estimated by GLS.

Gasoline for automobiles accounted for one-quarter of total petroleum products used in the transportation sector of Pakistan in 1981⁶. The regression results in Table IV-1 show that the signs of the income and price coefficients (elasticities) of the demand for gasoline are consistent with economic theory.⁷ The long-run income elasticity is greater than unity (2.21) as expected.⁸ Its value is relatively higher than that found in

⁶(1) Gasoline refers to both 'regular' and 'premium' varieties of petroleum (Motor Spirit) used in Pakistan for automobiles. Automobiles stand for cars and motor bicycles owned by private individuals in the country.

(2) Although the model discusses gasoline use by private owners of automobiles only, total gasoline demand by both private and public owners of automobiles is estimated. This is due to the absence of disaggregated data for the two groups of consumers separately.

⁷It is generally considered that private autos are common features of cities. This is because roads and highways are well developed in cities, maintenance and service stations are at hand, residential and working areas are generally located at short traveling distances, and the level of income is sufficiently high to maintain private autos and hire cab services. Therefore, we also estimated urban per capita gasoline demand with urban per capita income and the price of gasoline as explanatory variables. The results are not very different from the estimates obtained from national per capita gasoline demand. The regression results are given in Table IV-1. Since the choice of measures to calculate urban per capita demand and urban per capita income were arbitrary, we prefer to use national per capita consumption of gasoline for the analysis.

⁸Unfortunately, studies on gasoline demand of under developed countries are not available for comparison. Using the translog cost function, Uri [89] has estimated the own- and cross-price elasticities of energy demand for five different sectors of India. The own-price elasticity of demand for the total petroleum products in the transport sector is reported as -0.10.

Table IV - 1

Regression Results of Gasoline Demand in Pakistan (1961-81)

Regression Equations	Variables	Coefficients	t-value	R ² and F-ratio	h-stat/DW	Long-Run Elasticity
<u>OLS:</u>						
	Constant	-1.11	-0.63	R ² =0.87 F (3/17) = 38	h-stat = 2.05	Income =2.13 Price =-0.77
	National Income	0.28	1.93			
	Pgasoline	-0.10	-1.42			
	Lag. Var.	0.87	5.55			
<u>GLS:</u>						
	Constant	0.48	0.22	R ² =0.76 F (3/17) = 19	DW=2.01 ($\hat{\rho}$ =0.13)	Income =2.21 Price =-0.73
	National Income	0.33	2.00			
	Pgasoline	-0.11	-1.24			
	Lag. Var.	0.85	3.74			
<u>OLS:</u>						
	Constant	-1.10	-0.65	R ² =0.88 F (3/17) = 41	h-stat = 2.07	Income =2.54 Price =-1.01
	Urban Income	0.28	2.31			
	Pgasoline	-0.11	-1.55			
	Lag. Var.	0.89	5.54			
<u>GLS:</u>						
	Constant	0.63	0.29	R ² =0.77 F (3/17) = 19	DW=1.99 ($\hat{\rho}$ =0.14)	Income =2.61 Price =-0.98
	Urban Income	0.34	2.43			
	Pgasoline	-0.22	-1.21			
	Lag. Var.	0.77	3.60			

similar studies for developed countries.⁹ This difference can be explained from the theory of consumer preference. Due to the wider choice of goods and services, including automobiles, in rich countries, the services of automobiles may be considered a necessity. For a developing country like Pakistan, automobiles are luxury items. Therefore, we would expect that the income elasticity would be relatively higher in Pakistan than in developed countries [80].

The price elasticity is small in magnitude and is statistically not very significant. This may be due to the fact that the price of gasoline is controlled in Pakistan. This limits the movement of the price variable in the regression equation. Secondly, the price of gasoline for most of the estimation period remained constant or declined slightly in real terms. This reduces the effectiveness of regression estimation in producing significant parameter estimates. The price elasticity is generally close to the values reported for the developed countries, though its value is expected to be relatively small for Pakistan, because at low levels of income most energy is consumed as a necessity and as incomes grow, the additional use of energy becomes more discretionary.¹⁰

⁹The long-run income elasticities vary from 0.72 in studies done by Adams and others [1] on the pooled data (1955-69) of OECD countries to 1.74 in a study done by Kouris [52] on the pooled data (1956-73) of EEC countries.

¹⁰The price elasticity varies considerably in studies on gasoline demand in the United States. The long-run price elasticity ranges from -0.24, estimated by Houthakker et. al. to -1.50, estimated by Griffin [11]. The long-run price elasticity is reported as -0.40 in the study done by Adams et. al. [1] on

Therefore, at a higher level of income, there would be greater substitution from one form of energy to another due to changes in relative prices. This would produce a high price elasticity of demand for energy. But with the present state of technology, there is little room for substitution away from gasoline in either the developed or under developed countries. Therefore, the price elasticities are not expected to be very different.

3. Model of Fuel Demand by Other Transportation Modes

The determinants of demands for fuels in other modes can be expressed in terms of the following economic variables: income, prices of motor spirit and diesel oil and cost of fares can be determinants for fuel consumed by buses and trucks. The prices of furnace oil and coal, fares, capital expenditure on railroads and growth of GNP can be the explanatory variables for fuel consumed by the railways. These prices and GNP could also determine demand for fuel for ships. Fuel used in the airline services can be determined by the aircraft operating costs (including the price of jet fuel) and the growth in per capita income. Therefore, the demand for fuels by all modes of transportation can be approximated by the determinants of income, relative prices of fuel, fare rates and development of transportation infrastructure. ¹¹

¹⁰(cont'd) OECD countries and -0.76 in the study done by Kouris [52] on the EEC countries.

¹¹A complex system of tariffs and fare rates exists in different modes of transportation in the country. Data on the cost of fares of these modes are difficult to obtain. Therefore, cost of

The relationship between fuel demand and its determinants can be expressed in the following dynamic model [7;30].

The per capita desired demand for fuels (excluding gasoline) in the transportation sector of the economy in period t is Q_t^* . Q_t^* depends on n -variables, X_i (i =income, relative prices of fuels and transportation infrastructure etc.) in the following log-linear form.

$$q_t^* = \sum_{i=1}^n \alpha_i x_{it} + \omega_t \quad (6)$$

The partial adjustment between the actual and the desired consumption is given as in Eq.(4):

$$q_t = \phi q_t^* + (1-\phi) q_{t-1} + \varepsilon_t \quad (7)$$

Upon substituting Eq.(6) into Eq.(4'):

$$q_t = \phi \sum_{i=1}^n \alpha_i x_{it} + (1-\phi) q_{t-1} + \psi_t \quad (8)$$

$\phi \alpha_i, i=1, \dots, n$ are short-run elasticities. The long-run elasticities can be derived from Eqs.(13) and (14) shown in chapter II.

Since consistent time-series data for consumption and price of aviation fuel are available for the last twenty two years, Eq.(7) is used to estimate the demand for aviation fuel separate from other transportation modes.

 '(cont'd) fares is not included in the present estimation. However, their omission is not expected to affect the results. Cost of fares is related directly to the cost of fuels. Any increase in the price of a fuel, used in a particular transportation mode, would result in an increase in the cost of fare in that mode, though with some lag.

4. Regression Results of Aviation fuel Demand

The results obtained from OLS and GLS regressions are given in Table IV-2. The income and price elasticities of GLS estimates are significant at 5% level and consistent with theory. Urban per capita income was regarded as a better measure for capturing the effect of growth in income on air travel.

The role of price in the consumption of aviation fuel is complicated. A sharp increase in the price of aviation fuel might induce the airline to use more expensive resources more efficiently in the short-run. In the medium-run, the fare structure might be altered. In the long-run, new aircraft could be selected with a greater fuel-saving configuration. Thus the response to a price change would be distributed over time and would require a complex lag structure in the explanatory equation [30]. Unfortunately the data series available are not sufficiently long to estimate a more complex lag structure for the price.

Regarding income and price elasticities of demand for aviation fuel, the following facts are worth noting. In Pakistan, only a small proportion of the population, such as senior government officials and businessmen, travel by air. Recently Pakistani workers to the Middle East have become a significant proportion of the air travellers. Pakistan International Airlines (PIA) retains a monopoly for domestic

Table IV - 2

Regression Results of Aviation Fuel Demand in Pakistan (1961-81)

Regression Equations	Variables	Coefficient	t-value	R ² and F-ratio	h-stat/DW	Long-Run Elasticity
<u>OLS:</u>						
	Constant	0.67	0.43	R ² =0.81 F(3/17) = 25	h-stat = 2.03	Income = 1.16 Price =-0.16
	Urban Income	0.70	1.88			
	Paviation Fuel	-0.10	-1.12			
	Lag. Var.	0.40	2.00			
<u>GLS:</u>						
	Constant	-0.04	0.04	R ² =0.90 F(3/17) = 55	DW=1.99 ($\hat{\rho}$ = 0.10)	Income = 1.31 Price =-0.24
	Urban Income	0.76	2.47			
	Paviation Fuel	-0.14	-1.92			
	Lag. Var.	0.41	2.50			

flights. Due to the substantial increase in travel by workers abroad and the monopolistic control of the air service by the PIA in Pakistan, the demand for air services has increased substantially, even though there was a significant increase in the price of aviation fuel in the late seventies, resulting in increased air fares. The long-run income elasticity was 1.31 and the price elasticity was -0.24.

5. Regression Results of Fuel Demand by Other Modes

Due to the absence of segregated data for fuels used by railroads, trucks, buses and ships and for their determinants, these modes of transportation are analyzed jointly. However, it is worthwhile to make note of the following observations [30;61].

(1) Fuel used by the railroad should depend on the relative price of rail shipment and alternative forms of shipment such as trucks, and on the supply of these alternatives. Since railroads are capital intensive, an increase in the price of diesel oil, which is the main fuel for trucks, relative to the price of capital should result in a shift from truck to rail.

(2) Since bus technology changes slowly -- the diesel engine is highly developed and the maximum bus size is limited by law -- we should expect a slow reduction in the use of fuel due to technical progress over time. A high fuel price should result in an increased load factor, and increase in total

traffic, since intercity buses use less energy per passenger per mile than any other intercity mode.

(3) A major problem which arises in marine fuel estimation is the discretion of ship operators as to where they take on fuel. If ships calling at Karachi will also call at ports of other countries shortly before or afterward, the amount of fuel taken in Karachi need not be directly related to demand. If in Iran fuel price is substantially lower, very little fuel may be sold in Karachi. Thus an explanatory equation should also include the relative prices of fuel at Karachi and nearby competing ports. Lack of data on the relative price of fuel at different ports precludes including them in the present estimation.

The results for the income and price elasticities of joint fuel demand by railroads, trucks, buses and ships are presented in Table IV-3. ¹²

The income elasticity captures the effect of growth in GNP on transport demand and the resultant derived demand for energy

¹²Expenditure on the development of roads and other transportation infrastructure is a 'sine qua non' variable for the increase in the size of the transportation fleet and the demand for energy. The volume of cargo handled at Karachi is also likely to have a major impact on energy consumption in the transport sector, because Karachi is the point of origin and destination for major imports and exports of the country. In the estimation, first variable was captured by the lagged allocation of budget on road and transportation development in the various Annual Development plans of Pakistan [74]. The second variable was included directly. (Source: Statistical Yearbooks [69]). Neither variable significantly improved the R-square. The magnitudes of their coefficients were low and their statistical significance poor. Therefore, both variables were dropped from the final estimation.

Table IV - 3

Regression Results of Fuel Demand by Other Modes
of Transportation in Pakistan (1961-81)

Regression Equations	Variables	Coefficient	t-value	R ² and F-ratio	h-stat/ DW	Long-Run Elasticity
<u>OLS:</u>						
Constant		0.36	0.16	R ² =0.92 F(3/17) = 71	h-stat = 0.83 DW=1.76	Income =1.56 Price =-0.24
National Income		0.83	2.47			
Price		-0.13	-0.96			
Lag. Var.		0.47	2.18			

in a number of ways. First, it reflects the growth in the commodity-producing sectors of the economy. That is, it serves as a proxy for the level of freight movement of domestically-produced commodities. Secondly, it takes into account the income effect on demand for passenger traffic. The income elasticity in the transportation sector is thus expected to be large, i.e. a long-run income elasticity of greater than unity [97]. This gets support from the regression results.

The price elasticity is statistically insignificant, although it has a theoretically consistent sign. A large part of the energy demand in the transportation sector arises from freight movements in the country. However, the volume of movement of basic commodities is likely to be largely unaffected by increases in transportation costs due to increased prices of petroleum products. This is because, first, most of these commodities are transported on government account. In view of the importance of these commodities, wheat, rice, and cotton, both for domestic use and export, the transport bill is likely to be absorbed by the government through its general revenues. For example, the government has subsidized the movement of wheat in the country [72]. Second, even if some items, like cement, are moved on private account, these items are generally characterised by low price elasticities of demand. Third, as various transportation modes are in short supply, a rise in transport costs can easily be transferred to users in the form of higher prices. Finally, fuel cost is a small part of total

cost in the transportation sector. For these reasons, a statistically insignificant price elasticity is not unexpected.

V. AGGREGATE ENERGY DEMAND

The income and price elasticities of the sectoral demands for energy were analyzed in the previous three chapters. However, the elasticities estimated from the aggregate energy demand in this chapter may be more important because these elasticities provide simple summary parameters that may be easily understood and used. Many energy prices tend to increase together. An aggregate elasticity gives a rough estimate of the magnitude of the change in energy consumption resulting from pervasive changes in the energy situation, such as those caused by the sharp increase in the world oil prices in the early to mid-seventies. These estimates may thus be helpful in predicting the consequences of OPEC pricing strategies. Aggregate demand equation for energy may also give more robust and consistent projections, because errors resulting from the projection of demand for individual fuels are not cumulated into the projection of total energy demand.

However, the estimates obtained of the aggregate energy demand function obscure the substitution possibilities between the different types of energy used in the economy. Energy is not a single commodity; it is an aggregate of several commodities. Therefore, in order to measure the substitution possibilities between the different kinds of energy, the demand function for each fuel also needs to be estimated separately.

1. Model of Aggregate Energy Demand

In an economy, energy is demanded by producers as an input for producing commodities and services, and by consumers as an intermediate input for running energy-consuming capital stock. Therefore, a model for aggregate energy demand is developed in a general equilibrium framework.¹

The objectives of producers are to minimize the cost of production subject to producing a given level of output. Commodities Q_1, \dots, Q_n are produced by using capital, K , labour, L , energy, E , and intermediate outputs, M . The production functions, given the assumptions of constant returns to scale in each industry and the absence of dependency on intermediate outputs, can be approximated by a first-order Taylor expansion which is Cobb-Douglas. In log form:

$$q = \phi + \delta k + \omega l + \eta e \quad (1)$$

where ϕ is a constant column vector; δ , ω and η are diagonal matrices of elasticities which add up to the identity matrix; q , k , l , and e are column vectors of the logs of output and inputs listed by commodity.

The dual cost function of this production function is a Cobb-Douglas cost function. The cost function in log form can be

¹ See Nordhaus [65] and Erdman and Gorbet [28] for detailed exposition of the model.

written as:

$$c = \delta p_k + \omega p_l + \eta p_e - \mu \quad (2)$$

where c is column vector of the logs of long-run average costs. μ is a constant column vector. p_k , p_l , and p_e are column vectors of the logs of prices of inputs. They may be different from sector to sector. ²

Similarly, the objectives of consumers are to maximize utility functions subject to income constraints. Consumers' demand functions derived from utility functions depend on income, Y and prices, P . It will be assumed that (a) income is determined exogenously and (b) prices are set equal to a constant mark up, τ on the long-run average cost, C .

That is $P_i = C_i + \tau_i$.

Assuming Cobb-Douglas functions, then in log form the demand functions can be written as:

$$q = \theta + \psi p + v y \quad (3)$$

where θ and v are column vectors of constants, ψ is a diagonal matrix of price elasticities, p is a column vector of logs of prices and y is log of income.

Substituting Eq.(2) into Eq.(3):

$$q = \theta + \psi [\delta p_k + \omega p_l + \eta p_e - \mu + \tau] + v y \quad (4)$$

² p_k , p_l , and p_e are explained in detail in a latter part of this analysis.

To determine demand functions for individual sectors, Shephard's Lemma is applied to Eq.(2):³

$$E_i = \frac{\partial e}{\partial p_{ei}} = \frac{\partial C}{\partial p_{ei}} \frac{p_{ei}}{C} \quad (5)$$

Or

$$E_i = \frac{\partial e}{\partial p_{ei}} \frac{C}{p_{ei}} = \frac{\partial C}{\partial p_{ei}} \quad (6)$$

Or

$$E_i = \eta'_i \frac{C}{p_{ei}} \quad (7)$$

In log form, Eq.(7) can be written as:

$$e_i + p_{ei} - \eta_i'' = e \quad (8)$$

Similarly,

$$l_i + p_{li} - \omega_i'' = e \quad (9)$$

and

$$k_i + p_{ki} - \delta_i'' = e \quad (10)$$

³From Shephard's Lemma, the derived demand function of input i is the first partial derivative of the cost function with respect to the price of input i [92].

Or

$$e_i + p_{ei} - \eta_i'' = l_i + p_{li} - \omega_i'' = k_i + p_{ki} - \delta_i'' \quad (11)$$

where $\eta_i'' = \log(\eta_i')$ and so forth. Eqs.(1), (4) and (11) give $4*n$ equations for $4*n$ variables (q_i, k_i, l_i, e_i). Eq.(11) can be used to express k_i and l_i in terms of energy demand.

$$l_i = e_i + p_{ei} - p_{li} - \eta_i'' + \omega_i'' \quad (12)$$

and

$$k_i = e_i + p_{ei} - p_{ki} - \eta_i'' + \delta_i'' \quad (13)$$

for each $i=1, \dots, n$. Then putting Eqs.(12) and (13) into Eq.(1):

$$q_i = \phi + \delta [e + p_e - p_k - \eta'' + \delta''] + \omega [e + p_e - p_l - \eta'' + \omega''] + \eta e \quad (14)$$

Or

$$q_i = A + (\delta + \omega + \eta) e - \delta p_k - \omega p_l + (\delta + \omega) p_e \quad (15)$$

where $A = [\phi + \delta \delta'' - \delta \eta'' + \omega \omega'' - \omega \eta'']$.

Then since constant returns to scale implies $\delta + \omega + \eta = 1$,

Eq.(15) can be written as:

$$q = A + e - \delta p_k - \omega p_l + (\delta + \omega) p_e \quad (16)$$

Putting Eq.(4) for q into Eq.(16):

$$\begin{aligned} \theta + \psi [\delta p_k + \omega p_l + \eta p_e - \mu + \tau] + \nu y \\ = A + e - \delta p_k - \omega p_l + (\delta + \omega) p_e \end{aligned} \quad (17)$$

Or simplifying:

$$\begin{aligned} e = A' + (\psi \delta + \delta) p_k + (\psi \omega + \omega) p_l + (\psi \eta - \delta - \omega) p_e \\ + \nu y \end{aligned} \quad (18)$$

where $A' = [\theta - A - \psi \mu + \psi \tau]$.

Therefore, the demand equation for energy by the i th sector can be written as:

$$e_i = b_{0i} + b_{1i} p_{ki} + b_{2i} p_{li} + b_{3i} p_{ei} + b_{4i} y \quad (19)$$

where

$$b_{0i} = A_i$$

$$b_{1i} = (\psi_{ii} \delta_i + \delta_i)$$

$$b_{2i} = (\psi_{ii} \omega_i + \omega_i)$$

$$b_{3i} = (\psi_{ii} \eta_i + \eta_i)$$

$$b_{4i} = \nu_i$$

Now some further assumptions are made about factor prices.

(a) Note that the price of capital 'services' is given by $P_k = (r+v)P_c$ where r is the appropriate discount rate, v is the depreciation rate and P_c is the price of capital goods. In what follows we assume that the price of capital goods is linearly related to the price of the GNP or $P_c \sim P$, where P is the GNP deflator and $(r+v)$ is assumed to be constant over time.⁴ Then in log form

$$p_{ki} = \alpha_0 + p_i, \quad i=1, \dots, n \quad (20)$$

(b) The share of labour in national income is assumed to be relatively stable,⁵ and the price of labour is assumed to be proportional to the product of the GNP deflator and per capita output, or⁶

$$p_{li} = \alpha_1 + y, \quad i=1, \dots, n \quad (21)$$

Putting Eqs.(20) and (21) into Eq.(19) we obtain:

$$e_i = \beta_{0i} + b_{1i}p_i + (b_{2i} + b_{4i})y + b_{3i}p_{ei} \quad (22)$$

⁴ This assumption is empirically (1959-60 to 1970-71) supported by studies on the pricing of capital in Pakistan. See [34]. However, these figures are not available for the latter years of estimation.

⁵ The share of income of labourers in the manufacturing sector of Pakistan was almost stable during the period 1954-70 [35]. These shares have not been estimated for 1970s.

⁶ Following Kendrick & Sato [49], if labour's share is a constant fraction of GNP, we have $P_L L = \gamma_1 P X$ where X is GNP. Or $X = P_L L / \gamma_1 P$. If the labour force participation rate is constant then $L/N = \gamma_2$ where N is population. Thus we can relate per capita

income ($Y = PX/N$) and wages (P_L) as: $Y = PX/N = P(P_L L / \gamma_1 P) / N$
 Or $Y = P_L \left(\frac{L/N}{\gamma_1} \right) = P_L \frac{\gamma_2}{\gamma_1}$ In log form: $p_L = \alpha_1 + y$ where $\alpha_1 = \gamma_1 / \gamma_2$

Or $P_L = \frac{\gamma_1}{\gamma_2} Y$

where $\beta_{0i} = b_{0i} + \alpha_0 b_{1i} + \alpha_1 b_{2i}$.

Assuming homogeneity of degree zero of Eq.(19) in prices and income we have $b_1 + b_2 + b_3 + b_4 = 0$, so we can rewrite Eq.(22) as

$$e_i = \beta_{0i} + (b_{2i} + b_{4i}) y - b_{3i} p_{ei} - (b_{2i} + b_{3i} + b_{4i}) p_i \quad (23)$$

Or

$$e_i = \beta_{0i} + (b_{2i} + b_{4i})(y - p_i) + b_{3i}(p_{ei} - p_i) \quad (24)$$

Thus, finally

$$e_i = \beta_{0i} + \beta_{1i} y^* + \beta_{2i} p_{ei}^* \quad (25)$$

where

$$\beta_{1i} = (b_{2i} + b_{4i})$$

$$\beta_{2i} = b_{3i}$$

$$y^* = (y - p_i)$$

$$p_{ei}^* = (p_{ei} - p_i)$$

Eq.(25) gives the energy demand of the i th sector. ⁷

Total energy demand of all sectors of the economy can be obtained by summing Eq.(25) as:

$$e = \beta_0 + \beta_1 y^* + \beta_2 p_e^* \quad (26)$$

⁷Eq.(25) is not used for estimating sectoral energy demands, as this equation is derived from a general equilibrium framework. The general equilibrium analysis does not explicitly recognize the characteristics and the economic forces of each sector, which may be different from one sector to another. The difference in the sectoral characteristics of energy demand is achieved by developing energy demand models of each sector separately. See chapters II, III and IV.

where

$$e = \sum_i e_i$$

$$p_e = \sum_i p_{ei}$$

There is a time lag in the response of energy demand to changes in income and price of energy. A Koyck lag-structure for Eq.(26) is used for estimating short and long run impacts of changes in income and price on total demand for energy.⁸

2. Regression Results

The regression results are presented in Table V-1. The estimate of the income elasticity of aggregate energy demand is consistent with theory and is statistically significant. The value of the long-run income elasticity (1.17) is larger than that usually reported for the developed countries. For example, Nordhaus [65] has estimated a long-run income elasticity of 0.61 for West Germany, 0.78 for the Netherlands, 0.66 for Britain and 0.84 for the United States. Our estimate is closer to the value reported by Choe [15] on energy demand of different income groups in the non-OPEC developing countries. He has estimated a long-run income elasticity of 1.15 for a group of low-income countries in which Pakistan was included.

⁸See chapter I, pp.10-11 for the explanation of different lag-structures.

Table V - 1

Regression Results of Aggregate Energy Demand
in Pakistan (1961-81)

Variables	Coefficient	t-value	R ² and F-ratio	h-stat/ DW	Long-Run Elasticity
<u>Aggregate Energy*</u>					
<u>OLS:</u>					
Constant	0.73	1.67	R ² =0.97		
Income	0.76	3.15	F(3/17)	h-stat	Income
Price	-0.04	-0.25	= 257	= -1.97	=1.17
Lagd. Var.	0.35	1.60			Price
					=-0.06
<u>GLS:</u>					
Constant	0.74	1.93	R ² =0.98		
Income	0.68	3.11	F(3/17)	DW=1.95	Income
Price	-0.05	-0.39	= 382	($\hat{\rho}$ =-0.23)	=1.17
Lagd. Var.	0.42	2.12			Price
					=-0.09

* The h-statistic suggests the presence of first order serial correlation at 5% significance level. It is corrected by Generalised Least Squares (GLS) method of autoregressive process of order one [24].

The long-run price elasticity is statistically insignificant, though consistent with theory. Its value (-0.09) is less than the estimates for industrial countries as well as for other developing countries. The long-run price elasticities range from -0.49 to -0.89 for the industrial countries and -0.28 to -0.38 for the low-income developing countries ⁹[16;65]. The price elasticity for low-income countries is barely significant.

The following factors may account for the low and statistically insignificant value of the price elasticity of energy demand in Pakistan. For one thing, natural gas and electricity are the major commercial fuels, accounting for 63% of the total energy consumed in the country. The real average price of the two fuels has remained almost constant over the last twenty-two years. The supply of these fuels is controlled by public authorities. Limited variation in the real prices of natural gas and electricity may be the reason for low and statistically poor estimate of price elasticity. The real price of petroleum products, which accounts for 31% of total energy consumption, increased by 36%. This increase in the price of petroleum products was inadequate to reduce its consumption level for the following reasons. First, kerosene has been highly subsidized for equity and political reasons [20]. Second, industrial consumers may transfer the increasing price of oil to their customers by raising the price of their products. Finally,

⁹Choe has estimated the price elasticities by using time-series of 15 observations (1961-75) and a cross-section of 36 UDCs [16].

large and increasing remittances from abroad have provided an easy cushion for consumers to bear the burden of higher oil prices [26]. Therefore, the inverse relationship between demand and the (real) average price of energy was not adequate to produce a significant estimate of price elasticity.

3. Model of Individual Fuel Demand

The model for estimating individual fuel demand is developed from the translog price possibility frontier for the following reasons. The translog model does not impose a priori restrictions on parameters beyond those which arise from the assumptions of optimizing behaviour. The (constrained) translog model avoids the problem of multicollinearity by decreasing the number of parameters to be estimated. Here the system of equations are regressed simultaneously. As a result, the number of degrees of freedom does not pose any problem.

Furthermore, as the prices of all competing fuels are included in the estimation of the translog model, the degree and strength of the relationship between fuels can be observed more directly. The estimates of the translog model also provide price elasticities and elasticities of substitution for each observation (year). These estimates help in understanding the historical pattern of these parameters.

The methodology of the translog model can be briefly described by the following. Corresponding to the twice

differenciabile production possibility frontier, there exists a price possibility frontier of energy. The derivative of the log of the price possibility frontier of energy with respect to the log of price of a fuel gives the share equation of that fuel. The demand for fuels and elasticities of substitution between them are estimated from fuel share equations. The partial price elasticities of fuels are then computed from the estimates of the elasticities of substitution of fuels. ¹⁰

Zellner's iterative method of estimation is used to estimate three share equations for oil, electricity and natural gas. The fourth, the share equation of coal, is derived from the parameter estimates of the above three equations. Error term heteroscedasticity and autocorrelation within equations are ignored. The error correlations across equations are taken into account. The methodology is the same as described in the chapter for demand for factors and fuels in the industrial sector of Pakistan.

The translog model does not produce estimates of income elasticities, which may be critical in understanding the consumption pattern of different types of fuels and in projecting their demands relative to economic growth. Moreover, the price elasticities obtained from the translog model are partial elasticities. Total price elasticities from the translog model can be estimated from the formula given by Pindyck [80].

¹⁰For mathematical derivation of fuel share equations from the translog price possibility frontier of energy, see Pindyck [80] and Uri [89].

However, these estimates need additional information on percentage share of a fuel in total fuel expenditure, which can not be obtained from the data available for Pakistan.

The income and total price elasticities of demand for individual fuels can be obtained by applying OLS regression to Eq.(1), given in chapter I.

In log form it can be written as: ¹¹

$$f_{it} = \phi \beta_0 + \phi \beta_1 y_t + \phi \beta_2 p_{it} + (1-\phi) f_{it-1} + \epsilon_t \quad (I-1)$$

where

f_{it} consumption of ith fuel in the economy at time t.

p_{it} weighted average price of ith fuel in the economy at time t.¹²

y_t per capita income at time t.

To measure the substitution possibilities between natural gas, electricity, petroleum products and coal by the OLS method, prices of competing fuels are placed in the demand equation of each fuel.¹³ The choice of fuel prices as explanatory variables in each equation was arbitrary. Variables with poor statistical estimates and inconsistent theoretical relationships were

¹¹Note that Eq.(25) gives consumption of all fuels in the ith sector of the economy. What is needed here is the consumption of ith fuel in all sectors of the economy. However, Eq.(25) does not differ from the Eq.(I-1) in regression estimation.

¹²The price of a given fuel may vary from one sector to another.

¹³OLS estimates produce total cross price elasticities.

dropped from the explanation. This was necessary in order to increase the degrees of freedom, as only 22 observations were available for the estimation of each equation.

4. Regression Results

The results obtained from the OLS regression are given in Table V-2 and those obtained from the translog model are given in Tables V-4 and V-5. Except in a few cases, such as the own-price elasticity of electricity, the signs and statistical significance of the parameter estimates of the translog model do not vary from the results obtained by the OLS estimation. However, translog produces statistically more significant estimates of elasticities of substitution. It also makes the analyses richer by bringing all competing fuels together in the system of equations.

4.1. Income Elasticity

The income elasticities are estimated by the OLS method only. The income elasticities of all fuels, except for coal, are statistically significant and consistent with economic theory. The income elasticity of coal has a negative sign. The share of coal in Pakistan in total energy has declined consistently during the 22 years considered [70]. With the rising level of income, increasing urbanization, availability of modern

Table V - 2

Regression Results of Fuels in Pakistan (1961-81)

Regression Equations	Variables	Coefficients	t-value	R ² and F-ratio	h-stat/DW	Long-Run Elasticity
(1)	(2)	(3)	(4)	(5)	(6)	(7)
<u>Natural Gas</u>						
<u>OLS:</u>						
Constant		-3.72	-1.76			
Income		0.91	1.75	R ² =0.99		Income =3.51
Pngas		-0.22	-1.73	F(4/16)	h-stat = 0.16	Pngas =-0.88
Pkeros		-0.02	-0.26	= 510		Pkeros =-0.09
Lagd. Var.		-0.75	5.93			
<u>Electricity</u>						
<u>OLS:</u>						
Constant		-2.01	-1.98			
Income		0.77	2.99	R ² =0.98		Income =2.56
Pelect		0.12	0.29	F(4/16)	h-stat = 0.36	Pelec =0.41
Pngas		-0.10	-1.23	= 445		Pngas =-0.32
Lagd. Var.		0.69	8.90			
<u>Petroleum Products</u>						
<u>OLS:</u>						
Constant		2.44	1.43			
Income		0.32	1.73	R ² =0.80		Income =0.80
Ppetrl		-0.14	-1.22	F(4/16)	h-stat = 0.97	Ppetrl =-0.35
Pcoal		-0.11	-1.39	= 23		Pcoal =-0.27
Lagd. Var.		0.59	3.38			

Cont'd

(1)	(2)	(3)	(4)	(5)	(6)
<u>Coal</u>					
<u>OLS:</u>					
Constant	7.24	1.72			Income
Income	-0.36	-1.05	$R^2=0.89$	h-stat	=-0.75
Pcoal	-0.23	-1.14	F(5/15)	= 1.03	Pcoal
Pngas	0.20	1.89	= 36		=-0.48
Pelec	0.40	2.43			Pngas
Lagd. Var.	0.52	2.21			=0.43
					Pelec
					=0.82
<u>OLS:</u>					
Constant	17.44	3.53			Income
Income	-1.16	-3.04	$R^2=0.90$	h-stat	=-1.20
Pcoal	-0.25	-1.54	F(4/16)	= 1.02	Pcoal
Pkeros	0.35	2.98	= 39		=-0.26
Lagd. Var.	-0.04	0.17			Pkeros
					=0.37
<u>Kerosene*</u>					
<u>OLS:</u>					
Constant	-0.10	-0.13			Income
Income	0.69	1.83	$R^2=0.93$	h-stat	=1.40
Pkeros	-0.31	-3.64	F(3/17)	= 2.05	Pkeros
Lagd. Var.	0.51	2.53	= 75		=-0.61
<u>GLS:</u>					
Constant	-0.08	-0.12			Income
Income	0.63	1.81	$R^2=0.95$	DW=1.96	=1.39
Pkeros	-0.30	-3.97	F(3/17)	($\hat{\rho}=-0.20$)	Pkeros
Lagd. Var.	0.54	2.92	= 109		=-0.66

* The h-statistic suggests the presence of first order serial correlation at 5% significance level. It is corrected by Generalised Least Squares (GLS) method of autoregressive process of order one [24].

appliances, and increasing accessibility to electricity and natural gas by urban residents, consumers started switching from coal (or even kerosene) to more efficient fuels like electricity and natural gas.¹⁴ This also explains the low long-run income elasticity of kerosene compared to electricity and natural gas. In general, urban consumers are moving away from kerosene to natural gas and electricity, and rural consumers are switching from non-commercial fuels and coal to kerosene. Kerosene is available at a subsidized price in both rural and urban areas of the country; so its income elasticity is positive and significant in value.

The long-run income elasticity of petroleum products is low (0.80). This is an unexpected result, because petroleum products are assumed to be superior fuels in a developing country like Pakistan. Therefore, the income elasticity should be greater than unity. Compared to the growth in the consumption of natural gas and electricity, 32% and 27% respectively over 22 years, the consumption of petroleum products increased by merely 5%. Natural gas and electricity are supplied completely by domestic sources, whereas about 90% of the demand for petroleum products is met by imports. From this, one can conclude that petroleum products were perhaps subject to a supply constraints.

Secondly, 70% of petroleum products are consumed in the transportation sector. There are restrictions on the import of -----

¹⁴The average efficiency of different fuels is estimated as 0.31 for solid, 0.54 for liquid, 0.59 for gas and 0.78 for electricity [65].

various kinds of vehicles, and the vehicles which are allowed are subject to an import duty of 150% or more. Therefore, income earners abroad prefer to import home appliances like televisions, refrigerators, ranges, washers, driers, stereo components etc. These gadgets run on electricity and natural gas. Due to these reasons the long-run income elasticities of natural gas and electricity are very high.

Thirdly, the R-square for the petroleum products equation is low (0.80). This suggests that some other factors were not included in the equation for petroleum products, that could have pushed up the coefficient of income.

However, our estimate of the long-run income elasticity of petroleum products is close to the value (0.87) reported by Palmedo et.al. [76] for the transportation sector of a group of low income countries.

4.2. Own price elasticity

The own and cross price elasticities are estimated by both the OLS and translog methods. The own price elasticities of all fuels except for electricity are consistent with economic theory. The price elasticities of natural gas and kerosene are statistically significant, suggesting large increases in the demand for these fuels in response to a fall in their prices. The real prices of these fuels declined throughout the estimation period except for a marginal increase in recent

Table V - 3

Parameter Estimates of Share Equations of
Aggregate Energy Demand in Pakistan

	<u>t-value</u>
$\alpha_O = 0.7379$	14.730
$\alpha_N = 0.0812$	5.596
$\alpha_E = 0.1755$	4.167
$\alpha_C = 0.0054$	0.805
$\gamma_{OO} = 0.0208$	1.691
$\gamma_{ON} = \gamma_{NO} = 0.0397$	2.489
$\gamma_{OE} = \gamma_{EO} = -0.0562$	-6.406
$\gamma_{OC} = \gamma_{CO} = -0.0043$	-1.798
$\gamma_{NN} = -0.0034$	-1.580
$\gamma_{ON} = 0.0397$	2.489
$\gamma_{NE} = \gamma_{EN} = -0.0421$	-3.136
$\gamma_{NC} = \gamma_{CN} = 0.0058$	5.918
$\gamma_{EE} = 0.0747$	6.816
$\gamma_{NE} = -0.0421$	-3.136
$\gamma_{OE} = -0.0562$	-6.406
$\gamma_{EC} = \gamma_{CE} = 0.0236$	6.051
$\gamma_{CC} = -0.0250$	-3.146
$\gamma_{EC} = 0.0236$	6.051
$\gamma_{NC} = 0.0058$	5.918
$\gamma_{OC} = -0.0043$	-1.798

O = Oil
N = Natural Gas
E = Electricity
C = Coal

Table V - 4

Elasticities of Substitution of
Aggregate Energy Demand in Pakistan

	σ_{OO}	σ_{NN}	σ_{EE}	σ_{CC}	σ_{ON}	σ_{OE}	σ_{CC}	σ_{NE}	σ_{NC}	σ_{EC}
1960	-0.088	-19.48	-2.338	-15.41	8.870	-2.690	0.446	-52.97	13.67	18.08
1961	-0.129	-18.30	-2.217	-13.19	8.472	-2.232	0.541	-41.52	11.87	14.08
1962	-0.156	-24.09	-1.982	-11.65	5.164	-1.652	0.553	-43.50	14.62	11.83
1963	-0.159	-26.87	-1.837	-15.92	6.285	-1.382	0.427	-43.97	20.06	13.60
1964	-0.201	-19.91	-1.654	-15.66	9.117	-1.170	0.432	-29.57	15.68	12.06
1965	-0.274	-12.03	-1.364	-18.38	6.212	-0.844	0.354	-15.44	11.35	11.53
1966	-0.306	-11.86	-1.280	-14.91	6.164	-0.726	0.447	-14.28	9.732	9.464
1967	-0.222	-11.70	-1.612	-20.72	6.059	-1.089	0.297	-17.33	10.90	14.16
1968	-0.243	-11.23	-1.486	-23.67	5.890	-0.961	0.223	-15.50	12.76	14.56
1969	-0.523	-6.316	-0.681	-23.13	4.052	-0.209	0.227	-5.014	8.02	8.876
1970	-0.612	-5.817	-0.533	-19.11	3.873	-0.078	0.313	-3.958	6.686	7.197
1971	-0.623	-6.316	-0.480	-22.11	3.955	-0.035	0.233	-3.887	7.512	7.557
1972	-0.578	-5.911	-0.559	-24.83	3.906	-0.106	0.168	-4.171	7.998	8.662
1973	-0.545	-5.817	-0.615	-32.55	3.855	-0.143	-0.008	-4.295	9.405	10.64
1974	-0.338	-8.115	-1.118	-44.28	4.815	-0.566	0.228	-8.830	14.87	17.51
1975	-0.285	-6.652	-1.554	-25.44	4.112	-1.037	0.177	-9.833	8.869	15.79
1976	-0.274	-4.964	-1.201	-36.98	3.479	-0.657	-0.086	-5.838	8.924	16.60
1977	-0.349	-5.247	-1.334	-28.22	3.577	-0.802	0.107	-6.826	7.977	15.02
1978	-0.424	-4.859	-1.025	-36.98	3.432	-0.497	-0.091	-5.048	8.936	15.04
1979	-0.703	-4.357	-0.405	-31.59	3.288	-0.007	-0.005	-4.067	7.494	9.098
1980	-0.578	-5.000	-0.613	-32.55	3.524	-0.146	-0.011	-3.672	8.416	10.68
1981	-0.490	-5.147	-0.786	-44.28	3.566	-0.282	-0.246	-4.396	10.44	14.57
(t-value)	(-1.691)	(-1.58)	(-6.82)	(-3.14)	(2.49)	(-6.41)	(-1.79)	(-3.13)	(5.92)	(6.05)

Table V - 5

(Partial) Own - and Cross - Price Elasticities of
Aggregate Energy Demand in Pakistan

	η_{OO}	η_{NN}	η_{EE}	η_{OC}	η_{CN}	η_{OE}	η_{OC}	η_{NE}	η_{NC}	η_{EC}
1960	-.008	-.101	-.036	-.135	.046	-.042	.0039	-.275	.109	.159
1961	-.012	-.100	-.041	-.128	.046	-.041	.0052	-.228	.115	.136
1962	-.015	-.103	-.044	-.115	.022	-.037	.0054	-.187	.144	.134
1963	-.015	-.106	-.045	-.124	.024	-.034	.0033	-.171	.106	.106
1964	-.019	-.101	-.045	-.123	.046	-.032	.0034	-.150	.094	.095
1965	-.026	-.096	-.032	-.128	.049	-.027	.0024	-.123	.080	.080
1966	-.029	-.096	-.044	-.122	.050	-.025	.0036	-.115	.079	.077
1967	-.021	-.095	-.045	-.132	.049	-.030	.0019	-.142	.069	.090
1968	-.023	-.095	-.045	-.137	.050	-.029	.0012	-.131	.074	.084
1969	-.048	-.088	-.034	-.138	.056	-.001	.0013	-.070	.047	.052
1970	-.057	-.087	-.030	-.130	.058	-.004	.0021	-.059	.045	.049
1971	-.053	-.092	-.028	-.134	.057	-.002	.0014	-.056	.045	.046
1972	-.053	-.087	-.031	-.138	.057	-.006	.0009	-.061	.044	.048
1973	-.050	-.087	-.033	-.149	.057	-.007	.0000	-.064	.043	.049
1974	-.032	-.089	-.042	-.163	.053	-.021	.0008	-.099	.055	.064
1975	-.027	-.089	-.045	-.139	.055	-.030	.0009	-.131	.048	.087
1976	-.066	-.084	-.043	-.155	.059	-.023	-.0003	-.099	.037	.069
1977	-.033	-.085	-.044	-.144	.058	-.026	.0005	-.111	.041	.076
1978	-.039	-.091	-.041	-.155	.059	-.019	-.0003	-.087	.037	.063
1979	-.063	-.082	-.025	-.148	.062	-.001	0.000	-.077	.035	.042
1980	-.053	-.085	-.032	-.149	.059	-.007	0.000	-.062	.038	.049
1981	-.045	-.085	-.037	-.163	.059	-.013	-0.0004	-.072	.038	.054
t-value	(-1.69)	(-1.58)	(-6.82)	(-3.14)	(2.49)	(-6.41)	(1.798)	(-3.13)	(5.92)	(6.05)

years. It should also be noted that natural gas and kerosene were relatively inexpensive compared to other fuels. Natural gas was sold at less than its opportunity cost due to the presence of extensive recoverable reserves in the country [67]. The price of kerosene was fixed below the imported cost, because it is considered a "fuel for the common man" [38].

The own-price elasticity of electricity estimated by OLS has a positive sign but is statistically insignificant. The estimate obtained from the translog model has the correct (negative) sign and is statistically significant. The estimate of the price elasticity of electricity needs some explanation. With increasing urbanization and importation of electricity-consuming appliances by Pakistani workers abroad, the demand for electricity has increased by more than six times during the estimation period. Demand would have increased even more if the connection lines for electricity were available to more applicants. As reported by WAPDA, about 10% of the total applications for electricity connections have remained pending each year [36]. WAPDA did not recognise this as a case of "suppressed demand." It is argued that the pending applications reflected consumers' anticipation of administrative delays and as such they applied ahead of time for "future consumption". Perhaps due to these reasons, it is difficult to get correct estimates of the price elasticity of electricity.

The OLS estimate shows that the own-price elasticity of petroleum products is significant at the 10% level of

significance. The own price elasticity of coal is statistically insignificant. The translog estimation supports the results obtained by OLS and improves the statistical significance of the estimates of the price elasticities of petroleum products and coal.

4.3. Cross Price Elasticity

The OLS method measures the degree of complementarity and substitutability between fuels through the estimates of cross price elasticities. The translog model, on the other hand, produces estimates of elasticities of substitution. The cross price elasticity can then be computed from the estimates of the elasticities of substitution.¹⁵

The OLS results show that coal and kerosene are strong substitutes.¹⁶ These two commercial fuels are available in most rural and urban areas of the country. These fuels are also responsive to their own prices. Whenever the price of one fuel increases, consumers substitute the other fuel that has become more economical in use.

Natural gas and coal also appear as substitutes. When pipe lines for natural gas were completed in urban areas, consumers

¹⁵See chapter III, pp. 50.

¹⁶The elasticity of substitution between coal and kerosene is not estimated by translog method. Here kerosene is included as a part of petroleum products.

switched to natural gas. Natural gas is obviously a more efficient fuel for cooking and heating than coal. It is relatively inexpensive as well. At the same time, there seems to have been a large substitution from coal to natural gas in the industrial sector of the country.

It is difficult to defend the apparent substitution between coal and electricity on economic grounds. Coal and electricity each have their own specific use. Coal is used for cooking and heating and electricity is used for lighting and operating televisions, refrigerators, stereo components etc. It seems that as electricity became available in those areas where the pipe lines for natural gas were completed, and natural gas replaced coal, as explained earlier, the demand for electricity and natural gas has increased simultaneously. This has perhaps resulted in a positive estimated elasticity of substitution between coal and electricity.

Coal and petroleum products are complements in the OLS estimation and substitutes in the translog model. However, the cross price elasticity estimated by the translog model is negligible. Therefore, the relationship between coal and petroleum products is weak. One can observe that the industrial sector is the major consumer of coal. This sector also consumes 30% of total petroleum products. The consumption of both fuels has increased consistently in the industrial sector even when the income elasticity of coal was negative. This may have resulted in a complementary relationship between coal and

petroleum in OLS estimation.

The elasticity estimates from the translog model show that natural gas and electricity are strong complements. The two fuels again have their own specific uses. In the residential sector, electricity is used for operating household appliances and natural gas is needed for cooking. The industrial sector uses both fuels. However, the fertilizer and cement industries are major consumers of energy where only natural gas is used as a fuel. With urbanization and growth in per capita income, demand for both fuels has increased concurrently.

Petroleum products and electricity also appear as complements, though the relationship is not strong. About 70% of total petroleum products are used in the transportation sector, whereas all of the electricity is consumed in residential and industrial sectors. The consumption of the two fuels in two different sectors of the economy may have produced a (poor) complementary relationship between petroleum and electricity.

The substitutibility between petroleum products and natural gas may be because the industrial sector consumes 30% of the total supply of petroleum products and 85% of natural gas [68]. Apart from fertilizer and cement, other large-scale manufacturing industries, like food, paper, chemicals, need both petroleum and natural gas as fuels. Therefore, the relative prices of the two fuels may influence their demands in the industrial sector.

VI. CONCLUSION

The income and price elasticities of energy demand are important determinants in estimating the future need for energy and for analyzing the impact of increasing energy prices on other commodities. It has been observed that in the early stages of economic development, the demand for commercial fuels generally increases at a rate higher than the rate of economic growth. As industrialization proceeds, the proportion of fuels consumed in the traditional sector of the economy (wood, dung, bagasse, etc.) declines, and the demand for fuels in the modern sector (oil, gas, coal and electricity) rises [26]. It is these observations that get support from the results obtained in this study.

The parameter estimates of energy demand have shown that the values of the long-run income elasticities for most of the fuels have been greater than unity. The long-run income elasticities of natural gas and electricity have been high: 3.51 and 2.56 respectively. It is important to note that there was an ample supply of natural gas at a low price. However, connection of lines for electricity has not matched the number of applicants. The supply of oil was controlled by the federal government by regulation of local production and by a quota on imports. Coal has a negative long-run income elasticity of -1.20. With rising income levels, urbanization and

industrialization, consumers have shown a tendency to switch from coal to more efficient fuels like electricity and natural gas. In rural areas, where natural gas and electricity are not available, consumers apparently have moved from non-commercial fuels and coal to kerosene [70].

Price elasticity of demand has been an effective way of summarizing how changes in market price or quantity consumed affect each other. The long-run own-price elasticities of demand for all fuels consumed in the different sectors of the economy were small. The values of the long-run price elasticities ranged from -0.04 for COLKERO in the residential sector to -1.01 for gasoline in the transportation sector. Various factors could account for the low values of the price elasticities. The supply of fuels was generally controlled by government. The real prices of most fuels remained constant during the period under estimation. The real weighted average price of energy increased at an average rate of 0.95% per year [70]. The limited variability of prices of fuels during this period might have resulted in low and statistically insignificant estimates. Multicollinearity may be another reason which increased the standard errors and reduced the significance of parameter estimates.

Cross-price elasticities among fuels and other inputs are particularly important. They show how more than one fuel can be used for the same purpose. Between fuels and other inputs, cross-price elasticities reflect their complementarity or

substitutability in the production processes. The values of the cross-price elasticities obtained in this study were small and statistically not very significant. Labour and capital, and energy and capital were substitutes. The relationship between energy and labour was insignificant. Cross-price elasticities among fuels showed that oil and natural gas, natural gas and coal, and coal and electricity were substitutes, whereas oil and electricity, and electricity and natural gas were complements. The low cross-price elasticities might be due to the reasons given earlier.

From these results it appears that energy planning will be a formidable task. The income elasticity of energy has been fairly large. Any increase in income will lead to a more than a proportional increase in the demand for energy. The projected increase in per capita income by 3.2% and urbanization by 3.5% annually in the 1980s will result in a large increase in the demand for energy. On the other hand, the price elasticity of energy has been very low and statistically not significant. Price increases have not restrained very much the increasing demand for energy. The cross-price elasticities among different fuel types have also been low. The possibilities for interfuel substitution have, therefore, been limited.

In the short-run, the dilemma is whether to make the best use of the existing capital stock which has been relatively fuel-inefficient or to substitute new machinery and equipment which is more fuel-efficient. The dilemma is a real one when

total investable resources are in short supply and hence the energy sector is an important part of overall national planning and policy formulation.

The distribution and pricing of energy is another complex area that has raised serious social welfare and equity problems. The demand for energy has been price inelastic. A significant proportion of household expenditure in the lower-income groups has gone for fuels for cooking and lighting and as fares for mass transportation [87]. An improvement in their situation needs a rapid increase in their real incomes and/or a price policy that is not regressive.

However, the discriminatory pricing policy has certain undesirable consequences.¹ Cross-subsidization has produced an imbalance in production and consumption of local refinery output, which has led to import of middle distillates at premium prices and the export of heavy distillates at high cost, and has motivated gas stations to adulterate gasoline with kerosene. The price of natural gas, being far below its opportunity cost, has resulted in the misuse and massive substitution of natural gas. Differential prices of electricity to favour particular classes of customers has resulted in an unnecessarily complex tariff structure [96].

Some of these anomalies could be rectified by appropriate policy measures. An energy policy that has a balanced mix of

¹ The government pricing and non-pricing policies related to the management of energy demand are examined in detail in Appendix.

equity and efficiency is advisable at this stage. In Pakistan, a majority of the population is still dependent on non-commercial sources of energy for their daily activities and a large gap exists between the living conditions and pattern of energy consumption of the lower and high income groups in urban areas. Therefore, an energy policy must take into account the principle of necessity and equity. The objectives should be that the subsistence energy requirement for cooking and lighting is provided to the masses at affordable prices. ² Once that objective is realised, the principle of economic efficiency should be revitalised. The optimal use of exhaustible energy resources and the achievement of self-sufficiency in the energy sector should be the long-term targets of energy policy. This requires that in the long-run, the wellhead price of energy should reflect the international price of oil of similar quality. This policy should lead to a mobilisation of internal and external funds for investment in the energy sector. Consumer prices of energy should reflect the opportunity cost of using the resource. This policy should lead to an efficient pattern of energy consumption and make the consumers energy-conscious.

²The annual requirement of energy for subsistence level of activities, namely, cooking, lighting, subsistence farming and the minimal transport of food and fuel is estimated as 0.3 to 0.4 tce. This is less than 1 kgce per day per person [77].

APPENDIX: POLICY ISSUES RELATED TO ENERGY DEMAND

This study has focused on the demand aspects of the energy problems, the discussion here will also be limited to policy instruments used to affect demand. ¹These instruments are: (a) pricing, including taxation or subsidies, (b) laws, regulations and rationing, (c) conservation, and (d) education and information activities.

1. Pricing Policies

There are three basic considerations in formulating a pricing policy for energy: (a) economic efficiency, (b) social equity and (c) state revenues. The principle of efficiency seeks to ensure the regulation of prices in such a manner that the allocation of resources to the energy sector reflects fully their values in alternative uses. Prices of exhaustible domestic resources such as crude oil, natural gas, coal or hydro power storage capacity subject to siltation should reflect the foregone future net value of each of these resources.

The equity principle relates to welfare and income distribution considerations, which may call for charging

¹This study identifies problems and analyzes policy instruments for the years from 1961 to 1981.

different fuel prices to different users on grounds of allowing fulfillment of basic needs, such as lighting and cooking. It usually results in fixing higher prices for fuels such as gasoline consumed by the higher income groups, and charging relatively higher prices to the rich for the fuel consumed by all consumers such as electricity.

The revenue principle suggests that the energy supply systems should be able to raise enough revenues to assure continuity of service. A second objective may be to use taxation of energy resources as a means of raising required government revenues. The latter is an important consideration in Pakistan, where direct taxes, such as the income tax, do not generate substantial revenues both because the income base is small and the tax is poorly administered.

14.1 Pricing of Oil

The wellhead price of indigenous oil is fixed by the government. It is determined according to an agreement between the government and the oil companies, taking into account the international prices of crude of similar quality prevalent in the Persian Gulf area. Royalty, at the rate prescribed in the agreement, is charged on the wellhead price [71].

After an agreement in 1975, an increase in wellhead price has brought about an encouraging response, and it is anticipated that increased exploration activity by foreign petroleum

companies will lead to new oil discoveries. 'Old oil' wellhead prices have also been revised. Nevertheless, this issue requires further government attention to ensure that the possibilities for secondary or tertiary oil recovery from depleted fields are not being overlooked, because the current level of wellhead prices is still below a level needed to cover the higher cost associated with enhanced recovery techniques, even though these techniques would be economically justified [96].

Pakistan's refineries were on a self-financing basis until 1973. Since the end of the last decade, ex-refinery prices has been closely regulated and, as a result, they have lagged behind the successive increases in international crude prices. Recognizing the importance of self-financing, the government increased the ex-refinery prices by about 50% in March 1980 [96].

The government has also been reimbursing the shortfall in revenues over operating expenses of the country's major refineries through a system of equalization payments that assure the refineries a 15% return on paid up capital. These payments have not imposed a net fiscal burden on the federal government, since they are financed principally by a sizeable "development surcharge" (tax) on motor gasoline. However, this fixed return formula with its associated government contribution is cumbersome and provides little incentive to refineries to improve their operating efficiency.

The final sale price of the different oil products is based on five elements, which are all fixed by the government. These are (a) the ex-refinery price, (b) excise or custom duty, (c) a petroleum development surcharge, (d) distributors margin, and (e) the inland freight margin, out of which the marketing companies recover their actual transportation expenses [96]. The petroleum development surcharge is equal to the differential margin between the sales price and the "prescribed price" available to the oil marketing companies. It acts as a price stabilization measure which may contribute to the revenues of either the government or refineries.

The excise duty revenues contribute to the federal government's general tax revenues. Development surcharge receipts have, however, been used for three specific purposes since the oil crisis: (i) to cover the costs of refinery operations which have been running at a loss; (ii) to subsidize domestic prices of deficit input products (primarily kerosene); and (iii) to cover the transportation expenses of the marketing companies since the inland freight margins have been for the most part insufficient to meet actual expenses. Any residual development surcharge receipts have become part of the central government revenues [96].

The consumer pays a "fixed sale price" for a refinery product. The fixed price is determined by the sum of the above five elements. Consumer prices have the following features: (i) they now more closely reflect the economic cost of importing,

refining and distributing petroleum products; (ii) they are cross-subsidized in such a way that the higher priced motor gasoline subsidizes, in part, the prices of kerosene and light diesel oil; and (iii) they are geographically equal throughout the country.

The system of cross-subsidies can arguably be justified by the national social and economic goals. Its continued viability in the face of budgetary constraints and the changing pattern of demand for refinery products rests on frequent but realistic adjustments. For instance, in 1975 and 1976, the tax on gasoline was sufficient to pay for the shortfalls, but by 1977 excessive demand for subsidized fuels created a deficit which had to be made up from central government revenues. Cross-subsidies have generated imbalances in the demand for different petroleum products. The demand for subsidized products, light and middle distillates, exceeded the demand for other refinery output, e.g. naphtha and furnace oil. As a result, Pakistan is forced to re-export the latter at substantial costs, while importing large quantities of the former at premium prices [26].

To avoid such imbalances, the federal government has raised the retail prices of petroleum products on more than ten occasions between 1973 and early 1983 [66]. However, the prices of petroleum products have been lower in Pakistan than in several other underdeveloped countries. For instance, since 1973, the official price of crude petroleum in the world market has risen ten times, from \$3 to \$34 per barrel while domestic

prices have been increased by about 4.5 times from \$0.13 to \$0.60 per liter in 1982 [69].²

Market distortion has occurred due to imbalances in the demand for and output of petroleum products in the local refineries. Middle distillates (kerosene, JP-1, diesel, and light diesel oil) have accounted for about 65% of the total consumption of petroleum products, while local refineries have supplied only 46%, the rest of the demand has been met by imports. Of the refinery products, (including middle distillates) 65-75% have been usable in Pakistan, the rest (naphtha and furnace oil) have been exported. As a result, the demand for crude oil in Pakistan has been much higher than the aggregate demand for petroleum products [26].

In Pakistan, most of the oil has been imported and refined in Karachi. But about 60% of oil is consumed in the northern urban areas [26]. Therefore, substantial quantities of petroleum products are moved by rail from Karachi to the North. Severe bottlenecks often have occurred during peak energy demand. Until the new refinery at Multan and the addition to the Attock oil refinery in Rawalpindi have been completed, Pakistan will continue to experience complex logistical problems. In fact, the transportation system for oil products could encounter new bottlenecks if surplus products have to be moved from the northern refineries to Karachi for export.

²The exchange rate between Pakistani Rupee and US\$ is taken as US\$1 = Rs.9.90.

Finally, the geographical equivalence system, where the consumers in each region, irrespective of their geographical location, pay the same price for a petroleum product, needs to be monitored. This would be a necessary factor in ensuring that the benefits of this system (for example, allocation of fuels to very poor regions) have not been offset by abuses in the distribution system for refinery products. ³ Inland freight margins, which have recently been revised, need to reflect accurately the actual transport costs.

1.2. Pricing of Natural Gas

The wellhead price of natural gas has also been fixed by the government. This price has covered the amortization of expenditure on exploration and recoument of all development and operational costs. In addition, some profit has also been allowed in determining the wellhead price of natural gas. Purification, transmission and distribution charges for the gas companies have also been determined by the government [71].

The current wellhead price of natural gas has discouraged the producers from expanding this sector as fast as would be justified on the basis of the known natural gas reserves. With

³Petroleum products are sold at the same prices in all parts of the country. However, there is cost involved in transporting petroleum products from Karachi (where bulk of crude oil is refined) to the northern areas. As a result, distributors may reduce the required supply of petroleum products to the northern areas of the country.

the exception of the OGDC's exploration program, new exploration for natural gas has been almost at a stand still [67].

Consumer prices of natural gas have been based on a sliding-scale. For special consumers, such as the power, cement and fertilizer companies, a two-part tariff, comprised of a fixed charge and commodity charges has been prescribed. ⁴ Historically, consumer prices of natural gas have been fixed below the level of fuel oil prices in order to promote the use of an indigenous source of energy which has been relatively abundant. As a result, there has been a rapid expansion in the use of natural gas in the industrial, commercial and power sectors during the past two decades. Supply has not kept pace with the demand. Therefore, it has been necessary to devise a gas pricing policy which permits a larger increase in the supply of gas and reduces the disparity between the charges on gas and those on alternate sources of energy. The price of natural gas in 1982 was only one-third of the equivalent amount of fuel oil and one-fifth of kerosene. The government has proposed to raise gas prices to two-third of fuel oil prices by 1987-88 [67].

Attention should also be focused on the existing price differentials for natural gas between various categories of consumers. The power sector and certain industries, e.g. cement and fertilizer, as well as residential consumers have been

⁴For fertilizer, commodity charge is the same for all factories but the fixed charge is negotiated on a case by case basis. Cement factory charges vary not only by amount of natural gas consumed, but also by location [96].

charged prices that have been well below those paid by commercial consumers of gas. Although economies of scale in bulk supply would explain these differentials to some extent, it is unclear whether this is in fact the basis of the present tariff structure. The expansion of use of a two-part tariff system, which has already been in use for some but not all power and fertilizer plants, would be a more suitable method for achieving the objectives of efficiency and equity.

The wide gap between the consumer and producer prices for natural gas is bridged by a developmental surcharge tax. The surcharge tax has been an important source of tax revenue for the federal government, while an additional excise duty has been earmarked for the budgets of the provincial governments. A portion of the developmental surcharge has been used for financing the companies engaged in purification, transmission and distribution of natural gas.

1.3. Pricing of LPG

The pricing of LPG, which is a potential substitute for kerosene, gasoline and diesel, requires further examination. At present, LPG is priced at a higher level than any of these products. However, the supply of LPG from refineries is projected to grow to about 250,000 tons by 1985. Further there are possibilities of additional supply of LPG from the distillation of associated natural gas. Therefore, prices of

these fuels should be fixed at levels that would lead substitution from deficit output, kerosene, gasoline and light diesel to LPG [96].

1.4. Pricing of Electricity

Prices of electricity have been fixed by KESC, WAPDA, MESCO and REPCO in accordance with the pricing arrangements prescribed by the federal government. In fixing these prices, the government has ensured that the criteria agreed upon by these companies and the international loan-giving agencies are fully met [96].

Electricity pricing has been based on the efficiency principle to ensure an adequate financial return to the power-generating authorities. Equity and social considerations have also been an element of electricity pricing policy.

Although the power authorities recently have been better able to contribute to their investment programs from their own resources, both the level and structure of energy tariffs have become unnecessarily complex and badly distorted over time. The current tariff structure has been characterized by a variety of charges which have generally not been directly related to the costs of supplying electricity to consumers. In particular, the present capacity or KW charges have been well below the long-run

marginal costs (LRMC).⁵ Further, the low voltage consumer charges have been significantly below the costs of supply, particularly for residential consumers and for tubewells in the agricultural sector.

The government has recognized the extent and seriousness of these distortions and has commissioned a study, in collaboration with the World Bank, to propose a revised tariff for the power sector [96]. This study proposed raising the average price of electricity, supplied by WAPDA, by 38% in 1982. It also recommended a restructuring of the individual tariffs to correspond more closely to the LRMC of supply within a less complex categorization than has been presently the case.

Even with these proposed changes, power tariffs continue to have a number of anomalies which should be addressed in subsequent tariff revisions. For example, although the capacity charges will be raised to industry, they will still be considerably below the LRMC for the appropriate voltage levels. The tariff for private tubewells also needs to be raised. Some other major issues also remain to be resolved in tariff revisions in the future.

⁵The base price for any energy resource is determined by its LRMC. Marginal costs establish forward looking prices. Prices then reflect the real value of the additional resources that must be utilized in order to make another unit of energy available. LRMC must be used because of the capital intensity and indivisibility of most energy supply systems. The marginal costs include not only the current input and operating costs but should also provide for the investments that are or will be needed to supply the additional unit of energy. If prices are below this level, there will be a net economic loss in the long term [2].

First, the question of power losses needs further analysis. While losses are expected to drop from 34% of generation in 1979 to 25% by 1985, it is debatable whether such losses (which are considerably higher than normally-accepted levels) should be incorporated in the calculation of supply costs. To pass the technical losses directly to the consumer removes the power utility's incentive to reduce these losses.

Second, the KWh costs of electricity should more closely reflect the opportunity cost of the natural gas used in the power sector.

Third, the question of a uniform national tariff needs further examination. KESC has a well-established market with a high load density and its requirement for investment has been relatively small. The price of electricity, supplied by the KESC, therefore, has turned out to be lower than WAPDA's and its quality of supply has been at least as good. This higher price may have been a cause of discontent among the WAPDA consumers who have had to subsidize rural and tubewell consumers while also helping to finance a heavy investment program.

Fourth, WAPDA's installation policy must be reviewed. The appropriateness of the present policy of passing on the full connection charges, even to low income consumers or adding some of these costs to KWh charges, needs to be revised.

Finally, in subsequent tariff revisions, the demand forecast and load factors need to be more accurately estimated.

1.5. Pricing of Coal

Coal prices have not been controlled by the government. Private mine owners, who have been responsible for 75% of the indigenous supply of coal, have set their prices according to market conditions. PMDC, which produces the remainder, has set its price on the basis of open tenders [71].

Coal has been more expensive than natural gas. Natural gas is also more efficient in burning and has been more hygienic. This has resulted in a large displacement of coal, perhaps demonstrated by the negative income elasticity estimate for coal in this study. It is estimated that there are substantial recoverable reserves of coal which could generate 11% more energy than possible from the Sui gas field [58]. At this point, an in-depth study of coal needs to be undertaken to assess its potential as a future source of energy supply.

2. Other Considerations

The role of non-price policies, such as regulation and rationing, in economic management has been a contentious issue. However, the use of price policies need not exclude the usefulness of non-price policies. This will be particularly important in view of the apparent price inelasticity of demand for fuels. Imperfect market structures, resource constraints and

inequalities in the distribution of income have further justified the need for a judicious mix of price and non-price policies.

Conservation of energy has aimed at improving efficiency, or reducing the consumption of energy per unit of output. Some conservation could be brought about simply by doing without energy or by curtailing the level of certain energy-consuming activities.

Efficiency in energy use could also be achieved through the replacement of specific energy resources by less costly alternative energy resources, by labour, by capital or by a combination of all three. However, the results obtained in this study on the elasticities of substitution have shown that although substitution possibilities exist between energy and other inputs, such as labour and capital in the large-scale manufacturing sector of Pakistan, the extent of such substitution is rather limited.

Since price and non-price policies could vary greatly between economic sectors, the major policy issues of each sector will be discussed separately.

Energy for transport has posed severe policy and planning problems. Petroleum products have been the primary source of energy in the transport sector. Alternative fuels such as alcohol have not proven to be economically competitive even at the present-day oil prices [2].

Further, interfuel substitution in the transport sector has meant substitution between the by-products of refining petroleum -- petrol, diesel, kerosene and LPG. In other sectors, the possibilities of substitution between the primary energy sources, electricity, natural gas, petroleum products and coal, are considered. Such substitution in the transport sector could result in idling of the existing stock of automobiles and investment in more fuel-efficient stock. The question remains whether the purchase of new stock or the continuing use of relatively fuel-inefficient stock would be more economical for the country.

It should be noted that policies which have induced a shift from one type of refined petroleum product, such as petrol to diesel, have not affected the volume of crude oil input required for the output of other middle distillates. However, these policies have either led to an excess availability of the product being substituted (petrol) or the need for the importation of the substituting product (diesel). The situation could become critical when the surplus product turns out to be expensive to export.

Moreover, the government should be aware of the types of interfuel substitution which could nullify the desired shift in the demand for a particular fuel. For example, a substantial price differential between gasoline and kerosene could lead to adulteration of gasoline with kerosene. Kerosene could also be used to adulterate diesel fuel when the price differential

becomes sufficiently high. As a result, the consumption of kerosene would increase relative to other petroleum products. This could destroy the balance of refinery output relative to market demand and also result in financial losses to the government.

Conservation of energy in the industrial sector has been attained by reducing the use of energy or switching to lower-cost sources of energy. However, the added cost of such measures should not outweigh the savings in energy costs achieved.

Energy conservation in the industrial sector has been limited because the majority of industrial installations were built or designed in a period in which the real cost of energy was relatively low. As a result, savings in the capital and operating costs have been traded off against less energy-efficient processes. Most of them, moreover, have been based on the use of petroleum fuels or electricity produced from oil.

A study done by ESCAP [87] on the possibility of interfuel substitution in the industrial sector of the region, has concluded:

From eleven industry sectors and plethora of different processes and activities within each industry, relatively few energy substitution possibilities emerge as feasible within the short term except when indigenous sources of alternative primary energy have been developed to the extent that interfuel substitution becomes feasible given short-term technical feasibility and low additional capital investment requirements.

The results obtained in this study on the elasticities of

substitution between factors of production in the industrial sector have indicated that an increase in the price of energy relative to labour and capital may lead to a decrease in the consumption of energy. However, the strength of substitution has been weak enough that a relative price increase of energy could not be expected to lead to large investment in energy-saving capital stock.

Another problem is that lowering the amount of oil used through fuel switching has increased the energy coefficient of a particular products. An example of this has been the conversion from oil to coal for the generation of process steam. The additional equipment for coal handling, ash handling and air pollution mitigation would raise the internal power requirement of the process. Similarly, the process of obtaining adequate supplies of middle distillates has produced surplus output of the heavier distillates. Therefore, those industries which could substitute an additional input of heavier distillates need to be identified. The thermal power and cement industries appear to be potential areas for such substitution.

In the power industry, the substitution of indigenous natural gas for petroleum seems to be technologically feasible and commercially viable. There have been, however, major difficulties in the substitution of coal for petroleum. For example, conversion of an existing oil-fired station to the use of coal would require a thorough analysis of the power system, which should take into account, among other things, the shape of

the load factor, the number, sizes and types of existing plants and the likely sizes and types of future capacity. The choice also depends on such considerations as the space available for coal handling and storage, facilities for transporting coal and willingness of the authorities to accept the environmental problems associated with coal.

Households and commercial establishments have accounted for about 25% of the commercial energy and about 50% of the total (including non-commercial fuel) energy consumed in Pakistan [73]. Energy has been consumed primarily for cooking and lighting. In the upper-income brackets, a significant proportion of energy has been consumed by space-heating and air conditioning devices.

Electricity has been sold at a blocked price to favour low-income consumers. Prices paid by these consumers have been lower than those paid by the higher income consumers. ⁶ The social gain resulting from the progressive pricing structure of electricity needs to outweigh the loss of revenues.

Kerosene has also been sold at a subsidized price to benefit low-income consumers. It has encouraged diversion of kerosene from cooking to other uses, such as adulteration of diesel fuel and gasoline with kerosene. Pricing kerosene purely on commercial considerations would be regressive in effect, hitting hardest the low-income class. Therefore, a cost-benefit

⁶The price of electricity rises in blocks as the consumption of electricity increases.

analysis of such a policy would be necessary before its execution.

REFERENCES

1. Adams, F., H. Graham and J. Griffen. Demand Elasticities for Gasoline: Another View. Discussion Papers, No.279. Philadelphia: University of Pennsylvania, 1974.
2. Asian Development Bank, Asian Energy Problems. New York: Praeger, 1982.
3. Bakke, W.D. "Energy in Non-OPEC Developing Countries," in H. Landsberg, Ed. Selected Studies on Energy. Cambridge, Mass.: Ballinger Publishing Co., 1980.
4. Balestra, P. The Demand for Natural Gas in the United States. Amsterdam: North Holland, 1967.
5. ---- and M. Nerlove. "Pooling Cross System and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas". Econometrica. July 1966.
6. Barten, A.P. "Maximum Likelihood Estimation of a Complete System of Demand Equation." European Economic Review, 1. Fall 1969.
7. Beaton, W., J. Weyland and N. Neuman. Energy Forecasting for Planners: Transportation Models. Center for Urban Policy Research. State university of New Jersey. N.J., 1982.
8. Berndt, E.R. and L.R. Christensen. "The Translog Function and the Substitution of Equipment, Structure and Labor in U.S. Manufacturing 1929-68." Journal of Econometrics, 1. March 1973.
9. ---- and G.C. Watkins. "Demand for Natural Gas: Residential and Commercial Markets in Ontario and British Columbia". Canadian Journal of Economics. February 1977.
10. ---- and Wood. "Technology, Prices and the Derived Demand for Energy." Review of Economics and Statistics, 57. August 1975.
11. Bohi, D.R. Analyzing Demand Behaviour, A Study of Energy Elasticities. Published for Resources for the Future, Inc. Baltimore: John Hopkins University Press, 1981.
12. Burreight, B.K. and J.H. Enns. Econometric Models of the Demand for Motor Fuel. Report R-1561-NSF/FEA. Santa Monica, California. Rand Corp., 1975.

13. Canada, Ministry of Energy, Mines and Resources. Energy Demand Projections--- A Total Energy Approach. Report ER-77-4. Canada, June 1977.
14. Chateau, B. and B. Lapillone. Energy Demand: Facts and Trends. New York: Springer-Verlag/Wien, 1982.
15. Choe, J.B. "Estimation and Projection of Energy Demand in Developing Countries: Current State and Major Issues." in W. Hafele, Ed. Modelling of Large-Scale Energy Systems. Oxford: Pergamon Press, 1981.
16. ---- "Energy Demand in Developing Countries." in J. Derkerby, Ed. International Energy Strategies. Cambridge, Mass.: OG&H Press, 1980.
17. Christensen, L.R. "Transcendental Logarithmic Production Frontiers." Review of Economics and Statistics, 55. February 1973.
18. ----, D.W. Jorgenson and L.J. Lau. "Conjugate Duality and the Transcendental Logarithmic Function." Econometrica, 39. July 1971.
19. Clague, C. "Capital-Labour Substitution in Manufacturing in Underdeveloped Countries". Econometrica. March 1969.
20. De Kuijpu, M.A. "The Pricing of Petroleum Products in Pakistan." Pakistan Development Review. Vol.11. No.3. Autumn 1982.
21. Department of Energy. Draft Documentation Report on the Regional Demand Forecasting Model, 1977 Version. Prepared by Synergy, Inc. Washington, D.C., 1978.
22. Derkerby, J. "Estimation of Energy Demand: The Developing Countries." The Energy Journal. Vol.3, No.2. 1982.
23. Diwan, R.K. and D.N. Gujrati. "Employment and Productivity in Indian Industries: Some Questions of Theory and Policy." Artha Vijnana. March 1968.
24. Dutta, M. Econometric Methods. Cincinnati: South-Western Publishing Co., 1975.
25. Eads, G.C. The Local Services Airline Experiment. Brooking: Washington, 1972.
26. Ebinger, C.K. Pakistan: Energy Planning in a Vortex. Bloomington: Indiana University Press, 1981.

27. EMF4 Working Groups. "Aggregate Elasticity of Energy Demand." The Energy Journal. Vol.2, No.2. 1981.
28. Erdman, W.R. and F.W. Gorbet. "Energy Demand Projections for Canada: An Integrated Approach." in D. Nordhaus, Ed. International Studies of the Demand for Energy. Amsterdam: North-Holland, 1977.
29. Fuss, M.A. "The Demand for Energy in Canadian Manufacturing." Journal of Econometrics, 5. 1977.
30. ---- and L. Waverman. The Demand for Energy in Canada, Part I. Institute for Policy Analysis. University of Toronto, Canada, February 1975.
31. Gaude, S. "Capital Labour Substitution Possibilities. A Review of Empirical Evidence." in A.S. Bhalla (Edt) Technology and Employment in Industry. Geneva: International Labour Office, 1976.
32. Green, J. Consumer Theory. London: Macmillan Press, 1976.
33. Griffin, T.M. and P.R. Gregory. "An Inter-country Translog Model of Energy Substitution Responses." American Economic Review, 66. December 1966.
34. Guisinger, S.E. and K. Shahnaz "The Rental Cost of Capital for the Manufacturing Sector--- 1959-60 to 1970-71." Pakistan Development Review. Winter 1978.
35. ---- and M. Irfan "Real Wages of Industrial Workers in Pakistan: 1954-70." Pakistan Development Review. Vol.8, No.4. Winter 1974.
36. Hak, S.K. Energy Planning Models for Pakistan (Abstract). Proceedings, Asian Institute of Technology. November 1980.
37. Halvorsen, R. and Ford, J. "Substitution among Energy, Capital and Labor inputs in US Manufacturing." in R. Pindyck Ed. Advances in the Economics of Energy and Resources, Vol.1, pp. 51-75. JAI press Inc., 1979.
38. Hague, I.M. "Energy Planning in Pakistan: Problems and Prospects." Natural Resources Forum. Vol.6, No.1. January 1982.
39. Hoffman, Lutz. "Energy Demand in Developing Countries: Approaches to Estimation and Projection." Workshop on Energy Data of Developing Countries. Vol.1. Organisation for Economic Cooperation and Development. Paris, 1979.

40. Houthaker, S. and L. Taylor. Consumer Demand in the United States: 1929-70. Second Edition. Cambridge: Harvard University Press, 1970.
41. ----, P. Verleger, and D. Sheehan. "Dynamic Demand Analyses for Gasoline and Residential Electricity". American Journal of Agricultural Economics . No. 2. May 1974. pp. 412-418.
42. Iqbal, Mahmood. "Residential Energy Demand: A Case Study of Pakistan." Journal of Economic Studies. Vol.11, No.1. 1984.
43. ---- "Residential Demand for Natural Gas and Electricity in Pakistan." Pakistan Development Review . Vol.12. No.1. Spring 1983.
44. ---- "Estimates of Gasoline Demand in Pakistan". Simon Fraser University. 1984.
45. Javed, Anees. "Household Demand for Natural Gas in Pakistan". The Pakistan Development Review. Winter 1978.
46. Kemal, A.R. "Consistent Time Series Data Relating to Pakistan's Large Scale Manufacturing Industries." Pakistan Development Review. Spring 1976.
47. ---- "Sectoral Growth Rates and Efficiency of Factor Use in Large Scale Manufacturing Sector in West Pakistan." Pakistan Development Review. Winter 1979.
48. ---- "Substitution Elasticities in the Large Scale Manufacturing Industries of Pakistan." Pakistan Development Review. Spring 1981.
49. Kendrick, J. and Sato, K. "Economic Growth." American Economic Review. December 1960.
50. Kmenta, J. and R. Gilbert. "Small Sample Properties of Alternative Estimators of Seemingly Unrelated Regression." Journal of the American Statistical Association, 63. December 1968.
51. Kouris, G.J. "Energy Modelling: The Economist's Approach." in W. Hafele, Ed. Modelling of Large-Scale Energy Systems. Oxford: Pergamon Press, 1981.
52. ---- "Price Sensitivity of Petrol Consumption and Some Policy Indications: The Case of EEC." Energy Policy. Vol.6, No.3. September 1978.
53. Koutsoyiannis, A. Theory of Econometrics. London: Macmillan Press Ltd., 1973.

54. Layard, R.G. and A.A. Walter. Micro Economic Theory. N.Y.: McGraw Hill Book Co., 1978.
55. Lebel, G.P. Energy Economics and Technology. Baltimore: Johns Hopkins University Press, 1982.
56. Maddala, S.G. Econometrics. Tokyo: McGraw-Hill, 1977.
57. Magnus, J.R. "Substitution between Energy and Non-Energy Inputs in the Netherlands: 1950-1974." International Economic Review. Vol.20. No.2. June 1979.
58. Maubi, V. and J. Lee. "A Preliminary Analysis of Energy Supply and Consumption in Pakistan" (Draft). New York: Brookhaven National Lab., 1977.
59. Mause, Phillip. "Price Regulation and Energy Policy". in H. Landsberg, Ed. Selected Studies on Energy. MA: Cambridge, 1980.
60. McGillivray, R.G. "Gasoline Use by Automobiles", in Transportation Energy Conservation and Demand. Ed. Transportation Research Board. National Research Council. Washington, D.C., 1976. pp. 45-56.
61. Mooz, W.E. "Energy Trends in Their Future Effects Upon Transportation". Proceedings, Transportation Research Forum. Volume 14. No.1. 1973.
62. Murray P., R. Spann, L. Pulley and E. Beavris. "The Demand for Electricity in Virginia". The Review of Economics and Statistics. October 1978.
63. Naseem, S.M. Underdevelopment, Poverty and Inequality in Pakistan. Lahore: Vanguard Publications, 1981.
64. Norbye, K.D. "Are Consistent Time-Series Data Relating to Pakistan's Large-Scale Manufacturing Industries Inconsistent: A Comment." Pakistan Development Review. Spring 1978 and Winter 1978.
65. Nordhaus, D.W. "The Demand for Energy: An International Perspective." International Studies of the Demand for Energy Amsterdam: North-Holland, 1977.
66. Pakistan, Ministry of Finance. Pakistan Economic Survey, 1981-82. Islamabad.
67. ---- Pakistan Economic Survey, 1982-83. Islamabad.
68. ---- Central Statistical Office. Household Income and Expenditure Survey, 1971-72, Karachi.

- 69.---- Central Statistical Office. Statistical Year Books. Karachi. Different Years.
- 70.---- Directorate General of Energy Resources. Energy Year Book, 1981. Islamabad.
- 71.---- Energy Resources. Energy Data Book, 1979 . Islamabad.
- 72.---- Energy Resources Cell. Energy Forecasting Model: Projections of Pakistan's End Energy Consumption up to the year 2000. Prepared by ENAR Petrotech Services Limited, Islamabad, September 1979.
- 73.---- National Symposium on Energy Conservation . Islamabad, February 1980.
- 74.---- Planning Commission. The Fifth Plan, 1978-83 . Islamabad, 1978.
- 75.---- Planning Commission. "Estimates of Depreciations for West Pakistan." Mimeographed. Islamabad, 1978.
76. Palmedo, P.F. et.al. Energy Needs, Uses and Resources in Developing Countries. New York: Brookhaven National Lab., 1978.
77. Parikh, J.K. Energy Systems and Development: Constraints, Demand and Supply of Energy for Developing Regions. Delhi: Oxford University Press, 1980.
78. Pauchauri, R.K. Energy and Economic Development in India. N.Y.: Praeger Publishers, 1977.
79. Pindyck, R.S. "Interfuel Substitution and the Industrial Demand for Energy: An International Comparison." Review of Economics and Statistics. Vol.61. May 1979.
- 80.---- The Structure of World Energy. Cambridge, Mass.: MIT Press, 1979.
81. Riaz, T. "A Long-Range Energy Sector Plan for Pakistan." Pakistan Development Review. Autumn 1981.
82. Seweeney, James. "Passenger Use of Gasoline". Mimeo. Washington, D.C. Federal Energy Administration. 1975.
83. Sherman, M. Household Use of Energy in Pakistan. USAID, Islamabad, 1978.
84. Sicat, G.P. "Capital-Labour Substitution in Manufacturing in a Developing Economy: The Phillipines." The Developing Economies. March 1970.

85. Taylor, L. "The Demand for Electricity: A Survey". Bell Journal of Economics. Spring, 1975.
86. United Nations. "Energy Transition Through Demand Management: Long-Term Strategies and Policy Imperatives." Economic Bulletin for Asian and the Pacific. Vol. XXXII, No.2. December 1981.
- 87.----- Short Term Economic Policy Aspects of Energy Situation in ESCAP Region. Bangkok: ESCAP, September 1981.
- 88.----- Construction Industry. Monograph No.2. UNIDO, 1969.
89. Uri, D.N. "Energy Demand and Interfuel Substitution in India." European Economic Review. 1979.
- 90.----- "The Industrial Demand for Energy." Resources and Energy, 4. 1982.
91. Uzawa, H. "Production Functions with Constant Elasticities of Substitution." Review of Economic Studies. October 1962.
92. Varian, R.H. Micro Economic Analysis. N.Y.: Norton and Co. Inc., 1973.
93. Verleger, P.K. and D.P. Sheehan. "A Study of the Demand for Gasoline", in D. Jorgenson, Ed. Econometric Studies of US Energy Policy. Amsterdam: North Holland, 1976.
94. Williams, M. and Laumas, P. "The Relation between Energy and Non-energy Inputs in a Developing Economy." Mimeo. Dekalb, Northern Illinois University. 1980.
95. Wolf, C., D. Relles, and J. Navarro. "Oil Demand in Developing Countries." The Energy Journal. Vol.2, NO.4. 1981.
96. World Bank. Pakistan: Issues and Options in the Energy Sector. Report No. 2953-Pak. Washington D.C., 1980.
- 97.----- Energy Options and Policy Issues in Developing Countries. Working Paper No. 350. Washington, D.C., August 1979.
98. Zellner, A. "An Efficient Method of Estimating Seemingly Unrelated Regression and Tests for Aggregation Bias." Journal of the American Statistical Association, 57. June 1962.