ANALYSIS OF THE DEMAND FOR PETROLEUM REFINED PRODUCTS IN SAUDI ARABIA

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Submitted to the Faculty of the Graduate College
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In partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
December, 1987

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PETROLEUM REFINED PRODUCTS

IN SAUDI ARABIA

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ACKNOWLEDGMENTS

I wish to express my appreciation to Dr. Keith Willett, Chairman of my Graduate Advisory Committee, for his encouragement, personal guidance, valuable suggestions, and inspiration throughout the development of this research. It was the opportunity of working under his guidance that provided further incentives for me. Without his help, this study would not have been accomplished. A special debt of gratitude is also owed to Dr. Kent Olson for his valuable comments and suggestions. His kindness throughout my graduate period in economics is appreciated. Dr. Daryll Ray deserves a special thanks for his willingness to sacrifice his own time in being a member of my Graduate Advisory Committee and in helping me to solve some of the econometric problems which I have faced. His suggestions and comments are appreciated. I am also indebted to Dr. Orley Amos for his valuable comments and suggestions.

A special gratitude is expressed to my wife, Zakiah, my son Mohammed, and my daughter Fatima for their understanding, continual support, sacrifice, patience and encouragement throughout my graduate study in the United States. They have shared with me this endeavor which involved a large investment of my time and energy. This dissertation is therefore dedicated to my wife Zakiah, my son Mohammed, and my daughter Fatima.

My appreciation is also extended to my mother, my brother, my sisters, my relatives and my friends who had their part of suffering and sacrifices during my graduate studies in the United States.

A special thanks is due to Paul McClure for editing this manuscript.

Finally, Mrs. Julie Kemmerly and Mrs. Cloye Brower deserve a special thanks for excellent and fast typing.

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CHAPTER I

INTRODUCTION

Theoretical Aspects

Energy is an essential precondition for human survival. People demand energy for different purposes throughout their lives. Energy demand has been recently used as the basis for the maintenance of energy dependent systems or to produce output in excess of sheer system maintenance. Energy supply and demand derive their basis from the traditional assumptions of the pure theory of consumer and producer behavior. According to the theory of consumer behavior, the important factors that affect energy demand are as follows:[1]

(1) The price of the commodity under consideration;

(2) The consumer level of income;

(3) The size of the population;

(4) The price of other commodities, substitute or complement;

(5) Tastes and preferences of the population; and,

(6) Income distribution between individuals.

The theory of energy demand is founded upon the economic principle of diminishing marginal returns which underlies the conventional downward sloping demand curve. Consumers adjust their energy consumption to their

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[1] R.G. Lipsy, P.O. Steiner, and D.D. Purvis, Economics, (New York, 1987), p. 59.

income and the energy product price, assuming other things remain constant. Producers of energy products combine the available factors of production so as to produce a given level of output that maximizes their net profit.

Energy consumption is a reflection of the theory of consumer behavior derived from the demand for various nonenergy goods and services with which it is consumed. Therefore, if the supply and demand for nonenergy goods and services change, the consumption of the energy product will change. This implies that there is a relationship between energy uses and other economic activities. This relationship may be affected by the relative price of energy as well as the substitution possibilities in the economy.

In recent years a good deal has been written about the relationship between aggregate energy consumption and gross national product (Adelman (1980), Cooper (1980), Akara (1980), and Kraft (1978)). As an economy progresses and industrializes, it consumes more energy. In their studies, De Janosi and Grayson indicate that per capita consumption of energy is lower in the third world than in the developed countries. They indicate also that the response of energy consumption to a change in gross national product is lower in an industrialized country than in an underdeveloped country.[1]

Statement of the Problem

The recent development in Saudi Arabia has created an increasing demand for crude oil and oil refined products as well as other goods. Oil industry planning and development require much information about the

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[1]P.E. De Janosi, and L. Grayson, "Patterns of Energy Consumption and Economic Growth," Journal of Development Studies, Vol. 8, No. 2, (January, 1972), p. 241.

changing structure of the Saudi Arabian economy during the process of the nation's economic growth. More specifically, oil refined production can no longer be considered as exogenously determined. The economic situation in the Kingdom dictates such a fact.

Since 1983, the oil prices and production dropped from the high levels prior to 1982. In the summer of 1985, oil prices averaged $25.00 per barrel, with oil production fluctuating between two and three million barrels per day. In contrast in 1981 when oil price was $34.00 per barrel and 9.6 million barrels per day were produced. Because of this decline, Saudi Arabian problems have been more than just the loss of extra revenues to meet domestic development expenditures. The lower production has also had a great effect on the economy in terms of certain domestic industries and will continue to do so in the future. Oil production is not only an export product and a major source of foreign exchange; it is also closely linked to some domestic industries that depend on a specific level of crude oil production. As was mentioned by others, the Kingdom needs from two to three million barrels per day in the year 2000.[1] Most of this quantity will go to the refining industries in order to produce more refined products to satisfy domestic demand. For the time being, six refineries, with a capacity of more than a million barrels a day, supply the necessary fuels for the Kingdom's domestic market as well as export.

The problem of this study concerns itself with identification and analysis of the Saudi Arabian domestic demand for oil refined products. A demand curve for each petroleum refined product does not exist. A traditional demand approach is being used by Petromin. It was pointed out by one official that this

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[1] M. ElShayal, and A.S. Al-Zakri, "The Future of Energy Demand in Saudi Arabia," Vol. 7, No. 4, (1981), p. 342.

approach consists of personal judgment of what is needed for the next year. He pointed out that the previous year's consumption played an important part in this judgment.[1] So an identification of a demand curve for each product is important. It could be used to figure out the impact of price and income changes as well as estimating future needs. On the other hand, while the Kingdom oil reserves are large, Renshaw (1980) has concluded that most of the oil to be found in the Kingdom has already been discovered and the probability of future discoveries are low.[2] Therefore, it is vitally important that present and future levels of oil fuels demand be analyzed and projected with some precision. Such analysis and forecast would be of use to energy planners and decision makers. Energy planners and decision makers need more precise knowledge of the economic characteristics during the planning period. An understanding of fuel demand curves and elasticities becomes crucial in adopting different energy policies in the Kingdom.

Objectives of the Study

For Saudi Arabia, oil is the cornerstone of energy supply. It affects directly or indirectly all other sources of energy. Because of the dominant position of oil in the Kingdom's energy market, the fact that oil is a non-renewable asset, and the possibility of rising competition from established as well as new sources of energy, it is essential that a study of this type be conducted. Its main objectives are as follows:

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[1]Personal Conversation with Petromin Official.

[2]E.F. Renshaw, "The Decontrol of U.S. Oil Production," Energy Policy, Vol. 8, (1980), p. 44.

(1) To estimate the demand for the relevant petroleum refined products in Saudi Arabia.

(2) To analyze the domestic market structure for the petroleum refined products in Saudi Aabia in order to identify the key factors influencing the consumption of these products. This is achieved by analyzing the available information concerning the Saudi Arabian economy and domestic consumption of each individual petroleum product.

(3) To derive policy implications regarding the oil refined product market in Saudi Arabia.

(4) To compare the Saudi Arabian oil fuel demand elasticities with other estimations in developed and underdeveloped countries.

(5) To project future demand for the relevant petroleum refined products. This is achieved after a historical simulation is performed to validate the model specified in this dissertation.

A study of this kind in Saudi Arabia will attempt to identify the nature and complexity of the country's need for oil refined products. The results of a study like this will be important not only to the government, but also to the oil industry in Saudi Arabia. It is the goal of this study to point out the significance and importance of the energy demand analysis for the decision makers in the national government and to direct more attention to the domestic oil situation and its impact on the national economy. A better understanding of the energy demand structure of petroleum refined products is very helpful in formulating an overall energy plan for the country. Since Saudi Arabia, with a high oil reserve, is a member of the international community, an understanding of her domestic energy market is necessary to understand the international energy market. Saudi oil decisions may affect the international energy market both directly and indirectly.

Methodology

The methodology of this study employs both descriptive and statistical analysis. The descriptive method is used to analyze the energy aspects, the historical development of the oil industries, and the pattern and impact of oil revenues in Saudi Arabian economy. Statistical methods consist of using econometric techniques to derive and analyze the demand curves for gasoline, diesel, and kerosene. Three demand equations are specified. Each equation is rooted in economic theory and the institutional framework of Saudi Arabia. They also have some similarity in the energy demand literature. Those equations are estimated with ordinary least square techniques, using a time series annual data for the period 1967 to 1983. O.L.S. is used to measure the degree of the association between the fuels consumption and the explanatory variables in each case.

After estimating the three demand equations, an ex-post or historical simulation was carried out to validate the model. A five year projection was performed under four scenarios set for the period 1984-1988 for policy analysis purposes.

Dissertation Contribution

The contribution of this study lies heavily in the application of a well established theory and method to a relatively unexplored subject area. More specifically, the dissertation contribution consists of the following:

(1) Analyzing the Saudi Arabian energy market in general and the three fuels studied in particular.

(2) Developing an econometric model of the petroleum refined products

demand in question by incorporating a functional form relationship of the consumption of each fuel and the key related economic variables.

(3) Testing the applicability and the validity of the model by carrying out an ex-post simulation and future forecast.

The Nature of the Data

A major problem encountered in developing econometric models for less developed countries is the difficulty in obtaining reasonably good time-series data for good estimation results. In some of these countries, data are scarce. In those countries where data does exist, the data is neither precise, nor well defined nor organized. In the cases where data is available, it is very difficult to decide which data to use since it appears in several publications that contradict each other. In some of the data cases, the rule of prices is difficult to determine. Pindyck (1979) pointed out that:

> The first and most serious problem is that for most of the countries there is little good data available, particularly for the retail or wholesale prices of various fuels. Thus, even where fuel quantity data is available (which it is at least on an aggregate level of a number of developing countries), it is impossible to estimate econometric models specified to explain the role of prices (p. 249).

Moreover, data may not be adequate or published in aggregate or disaggregate levels. In this case, J. Dunkerly (1982) has said:

> There are, unfortunately, in many countries inadequate data to support even the more modest scope of activity. On the side of energy consumption, data are typically available for total commercial energy (i.e. petroleum, gas and electricity) for a considerable period of time, about twenty-five years. A major drawback is that data are not always available on a disaggregate end-use sector basis (p. 87).

In the Arab world, composed entirely of less developed countries with different degrees of modernization, energy data are scarce. If data are available in some of these countries, they are neither organized nor classified properly.

Available data in the Arab world are not complete and a breakdown may occur over time. A good time series set may not be available. In this case, Dr. I. Ibrahim (1985) mentioned that:

> Available energy data in many Arab countries suffer from inappropriate methods of classification with regard to energy demand modeling. Primary energy and secondary energy consumption usually are not distinguished. Utilized data that include energy used for conversion and transformation introduces a major specification error to energy demand models, as this type of use is related more to the supply function than the demand function. This problem is most serious in the Arab-oil exporting countries where the amount of energy used for conversion could be great relative to their domestic energy consumption (p. 136).

Al-Janabi (1979) points out the nature of data in the OPEC countries as follows:

> The poor quality of statistical information makes it difficult to find reliable data on past trends in the economic indicators of developing countries, including OPEC countries. In the case of internal energy consumption data for OPEC countries, the definitions of the various categories of fuel use vary from country to country, thus making aggregation difficult. Probably the best statistics on internal energy consumption and hydrocarbon use in OPEC member countries are for refined petroleum products (p. 87).

In collecting the available data in less developed countries, the researcher may have to make a field trip and use his personal influence to release whatever data he or she needs.

The problem that is encountered in this econometric study is related to the small sample size used in estimating the demand equations for petroleum refined products in question in Saudi Arabia. Data, which are annual, are only available in a reliable form for the period 1967-1983. This was the largest sample size for most of the variables used in the model.

In Saudi Arabia, especially after 1970, the quantity and quality of data collection and publication have been improved and become more reliable and fairly well organized. A great concern with data collection had been undertaken in most of the government agencies as part of the first development plan objectives which started in 1970. From here on, data collection and organization were emphasized and special statistics departments were established in each ministry for these purposes.[1]

Having explained the nature of the data in less developed countries and particularly in Saudi Arabia, the following data sources represent the more realistic figures that fit our model estimation.

Petroleum Product Data

Due to the differences in the international publications, historical data on gasoline consumption were taken mainly from two major sources: the Petroleum Statistical Bulletin of Saudi Arabia and the Saudi Arabian Monetary Agency Annual Reports. Kerosene data were taken from The United Nations Energy Statistical Yearbook. Consumption of diesel for the period 1970-1982 was taken from the Petroleum Product Prices and Their Component in Selected Countries. Other diesel observations were obtained by personal contact with the Arabian American Oil Company and the Ministry of Petroleum and Mineral Resources.

Prices Data

The United States Department of Energy publishes a worldwide petroleum products price data. Although this is a very good source, in some cases it is not complete. Our time series price data were obtained from the following sources:

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[1]M.M. Shams, "Oil Conservation and Economic Development in Saudi Arabia," (Unpublished Ph.D. Dissertation, The University of Texas at Austin, 1984), p. 5.

(1) Retail prices for petroleum refined products were obtained from the Ministry of Commerce by personal contact and from The Statistical Yearbook of Saudi Arabia.

(2) Natural gas retail price data were obtained from the Ministry of Commerce by personal contact and from The Statistical Yearbook of Saudi Arabia.

Income and Population Data

The International Monetary Fund publishes nominal and real income statistics together with other financial and monetary data. However, actual GNP expenditure for the period 1967-1983 was taken from The Statistical Yearbook of Saudi Arabia. On the other hand, population figures were taken from the International Financial Statistics published by International Monetary Fund.

Organization of the Study

This study consists of seven chapters. Chapter I, the present chapter, is an introduction to this study. It deals with the problem identification, dissertation objectives, methodology, contribution and the nature and sources of the data.

Chapter II presents an overview of the relevant literature in the demand of petroleum refined products. An overview of some studies in the Saudi Arabian energy and oil situations is also presented.

Chapter III examines the nature of Saudi Arabia's economic growth and highlights the importance of energy sources as well as the Kingdom's dependence on oil. The changing patterns of oil fuels and other energy source demand and supply are examined. The specific factors that influence model formulation are discussed.

Chapter IV presents the conceptual and methodological framework of the study. An econometric model of the demand for petroleum refined products in Saudi Arabia is presented. The general nature of each demand equation is presented. The explanatory and the endogenous variables as well as some econometric problems are analyzed.

Chapter V presents the estimation results of each petroleum refined product under study. It also presents a comparison of the estimated price and income elasticities of Saudi Arabia and the estimated price and income elasticities of other nations.

Chapter VI examines some policy issues. It develops a historical simulation and projection of the petroleum refined products in question. Four scenarios are considered under alternative assumptions.

Finally, Chapter VII summarizes the disseration and presents some implications and conclusions.

CHAPTER II

SURVEY OF THE RELEVANT LITERATURE

This chapter provides a review of the relevant literatures on demand for consumption of petroleum refined products and the Saudi Arabian energy and oil situation.

The Literature on the Petroleum Refined Products

In the oil market, a wide range of theoretical and empirical studies have been undertaken and the most important and relevant to the present topic are briefly outlined.

Pindyck (1979) estimated demand elasticities for various petroleum refined products in two developing-country groups. Greece, Spain and Turkey constitute one group and Brazil and Mexico the other. The equations for Greece, Spain and Turkey are estimated for each of six petroleum products and those for Brazil and Mexico are estimated for four petroleum products only. A log-linear model with a Koyck lag to explain the dynamic adjustment of demand to changes in income and price are used. The general form is as follows:

$$\text{Log } q_{ijt} = \alpha_{ij} + \beta_i \log y_{jt} + \gamma_i \log p_{ijt} + \lambda_i \log q_{ij\,t-1} + e_{ijt}$$

where:

q_{ijt} : per capita consumption of fuel i in country j at time t.

y_{jt} : per capita gross domestic product in country j at time t.

p_{ijt} : price of fuel i in country j at time t.

In some cases, he mentioned that additional variables, such as temperature and price of other fuel, are included in the above equation.

Data which are annual for Greece, Spain, and Turkey span 1955 through 1975 while Brazil and Mexico span the periods 1954-1974 and 1960-1974, respectively.

The results for Greece, Spain and Turkey show that light fuel oil, motor gasoline, and diesel fuel appear to be price inelastic but highly income elastic. Heavy fuel oil, on the other hand, is highly price elastic but less income elastic. The demand for kerosene is price inelastic and has a negative income elasticity. For other petroleum products, own-price elasticity is large.

The results for Brazil and Mexico show that light and heavy fuel have low price and income elasticities. Gasoline, on the other hand, is price inelastic and income elastic. Kerosene has a very small price elasticity and its income elasticity is insignificantly different from zero. The liquified petroleum gases show a moderate price elasticity and a large income elasticity.

Pindyck mentioned that the above results are consistent with the following explanation:

(1) There is some evidence that in the developing countries price elasticity of energy demand tends to be smaller, but income elasticity tends to be larger than in the developed countries. His explanation would apply largely to the residential and transportation sectors which, for developing countries, represent a greater fraction of total demand.

(2) In the residential sector and the transport sector, it is likely that price elasticities of energy demand are lower because at low levels of income most energy is consumed as a necessity; as income grows,

the additional use of energy becomes more discretionary, allowing for greater substitution away from energy if prices rise.

(3) Low-price elasticities and high income elasticities in the residential sector do not necessarily mean that the LDC's will consume much more energy as their per capita income increases.

(4) In the industrial sector, the GDP elasticity of energy demand has been historically lower in the developing countries. However, it may be higher if their economic structures become similar to the economic structures of developed countries.

(5) There is likely to be greater substitutability between energy and capital for many of the developing countries. This means that price elasticity of the industrial demand for energy is greater for the LDC's as labor and capital can be substituted for energy to a greater extent. For this reason, energy demand in the industrial sector should be more price elastic in the developing countries because of the greater ability to substitute low-priced labor.

Ezzati (1976) evaluated the world oil market and OPEC's revenue-maximizing price strategy. He used a world oil model similar to Houthakkar and Kennedy to obtain the equilibrium for supply and demand and prices for crude oil and petroleum refined products for major regions of the world. His model is a long-term general equilibrium one, using a nonlinear programming algorithm. It consists of four segments: crude production, transportation, refining, and consumption of products. He divided the world into six regions: United States, Canada, Latin America, Europe, the Middle East and Africa, and Asia. The products considered for analysis are crude oil, gasoline, kerosene, distillate and residual fuel oil. The model assumes competitive markets and both transportation and refining have constant returns to scale and operate at constant long run marginal cost. In his model, supply of crude oil is expressed as a function of crude oil prices. The demand for each petroleum product is expressed as a function of price and income. Zero cross-price elasticity is assumed among the petroleum products. However, no estimation for those petroleum refined products is presented.

The major conclusion reached by this study is that the present level of OPEC prices will not be revenue-maximizing in 1980 and higher prices could be charged by OPEC members if they decide to maximize their income as a group.

Houthakkar, Verleger and Sheehan (1974) used gasoline and residential electricity pooled time series data for different states and fitted it to a dynamic demand function of the flow adjustment type. They estimated the demand as a function of real income, price level and last period demand, using the following dynamic model:

$$\ln q_{it} = \theta \ln a + \ln p_{it} + \theta \beta \ln y_{it} + (1\text{-}\theta) \ln q_{i,\, t\text{-}1}$$

where:

q_{it} : demand for product i at time t.

p_{it} : price of product i at time t.

y_{it} : real per capita income at time t.

θ, α, γ, β are parameters to be estimated.

The above equation was estimated using annual data for electricity and quarterly data for gasoline for 48 states. The results for gasoline are as follow:

short-run price elasticity	.075
short-run income elasticity	.30
long-run price elasticity	.24
long-run income elasticity	.98

Kennedy (1974) described the structure of a regional multicommodity economic model of the world oil market and presented some results from it for use in forecasting and policy simulation. The model is a partial equilibrium model, static and long-run in nature. The model consists of four segments: crude production, transportation, refining and consumption. The model covers six regions: United States, Canada, Latin America, Europe, the Middle East and Africa, and Asia. The model used five commodities, four of which were refined products.

The part of the Kennedy model most relevant to our study is the set of demand and supply equations for petroleum refined products. Those equations were estimated as a function of price and income from annual time series data for a number of OECD countries. The results are based on the following dynamic flow adjustment model:

$$\log q = \log a + (1 - \lambda)\,\beta \log y + (1 - \lambda)\,\gamma \log p + \lambda \log q_{-1}$$

where:

y : deflated per capita income.

p : price deflated by CPI.

β, γ : long-run elasticities.

$(1 - \lambda)\,\beta$ and $(1 - \lambda)\,\gamma$: short-run elasticities.

q : quantity consumed from each product in per capita term.

The estimation results indicate the following:

(1) Gasoline long-run income and price elasticities are estimated to be 1.3 and -.82, respectively.

(2) Kerosene long-run income elasticity is -2.5, indicating that kerosene is an inferior good. The long-run price elasticity for kerosene is rather high, -2.0, indicating the existence of a substitute good.

(3) The long-run income elasticity for distillate fuel is 2.8, indicating that it is a superior good. The long run price elasticity is -.76.

(4) The long-run price elasticity for residual fuel oil is very high, -1.58. The long-run income elasticity for residual fuel oil is 1.6.

Pagoulatos (1975) estimated the demand, the export and the import of crude petroleum equations together with a supply equation for the United States. Eleven equations were estimated, one for each petroleum refined product, except for road oil and asphalt. Dynamic and/or static equations were used. The refined products that were evaluated and analyzed are: gasoline, coke, residual fuel, lubricants, wax, still gas, liquified fuel, petrochemical feedstock, distillate fuel, kerosene, road oil and asphalt. The data, which are annual, cover the period 1959-1972. The dynamic equations that are estimated are of the following form:

$$\log F_t = \lambda \log x + \lambda \beta \log p_t + \lambda j \log y_t + (1 - \lambda) \log F_{t-1}$$

where:

x : constant term.

p_t : price deflated by consumer price index.

y_t : per capita income.

F_{t-1} : per capita demand in year t-1.

The relationship is also estimated with static framework in the following form:

$$F_t = \lambda \log x + \lambda \beta \log p_t + \lambda j \log y_t.$$

In some situations, capacity variable or a time trend variable were added. In another situation, a proxy variable of price is used.

The results of the estimated elasticities can be summarized in Table I. No further discussion of the results were provided.

TABLE I

SUMMARY OF PAGOULATOS STUDY

	Dynamic Model				Static Model	
	Price Elasticity		Income Elasticity		Price Elasticity	Income Elasticity
	LR	SR	LR	SR	LR	LR
Gasoline	-.95	-.102	1.49	.16	-.54	.07
Coke	--	--	.1517	.0613	-.17	.59
Residual Fuel	-.1653	-.016	2.7228	.275	--	--
Lubricants	-.52	-.301	2.96	1.27	--	--
Wax	-2.42	-.44	1.95	.35	--	--
Still Gas	-.43	-.10	.73	.18	-.53	.11
Road oil & Asphalt	--	--	.50	.39	-.18	.67
Liquified Fuel	--	--	--	--	-.06	1.2
Petrochemical Feedstock	--	--	--	--	--	1.83
Distillate Fuel	--	--	--	--	-.78	.33
Kerosene	-6.36	-4.74	.24	.18	-3.71	.64

In a subsequent paper, Pagoulatos and Timmon (1979) published the previous work in an article. In this paper, the total number of refined products estimated are reduced to only 10. Each of the ten demand equations is specified as a function of per capita income, its own price, and the price of close substitutes. An estimation of those ten demand equations was presented. However, no discussion of price and income elasticities was attempted.

Projections were made to 1985 under alternative assumptions regarding real income and prices.

In a Ph.D. dissertation Kianian (1983) esitmated and projected five linear demand functions for gasoline, kerosene, gas oil, fuel oil, and total refined products for Iran. He used a time series annual data for 1955 to 1978. He ended up preferring the use of real GNP per capita, real price deflated by CPI, and last year per capita demand variables in the estimated function. In some cases, he added other related variables such as the price of a substitute to the good in question. The results of his estimation of price and income elasticities can be summarized in Table II. As shown in this table, both short and long-run price elasticities for each product in question over ten time periods were downward sloping in all cases under consideration. He also compared those elasticities with other studies in developed and developing countries. As it is shown in the table, his estimate of short-run and long-run price elasticities for gas oil, fuel oil, and total have positive signs. No explanations were given for these results.

TABLE II

SUMMARY OF KIANIAN STUDY

	Income Elasticity		Price Elasticity	
	SR	LR	SR	LR
Gasoline	.2308	.9139	-.0084	-.0333
Kerosene	.2002	1.0028	-.0487	-.2439
Gas Oil	.1776	2.34	.0454	.5983
Fuel Oil*	.2397	1.190	.0696	.3456
TOTAL	.1739	2.359	.1257	1.706

* In estimating fuel oil, real mineral and industrial products were used instead of income.

Review of the Literature on the Saudi Arabian Oil and Energy Situation

Econometric studies of energy supply and demand for petroleum refined products in developing countries, such as Saudi Arabia, are very limited and scarce. However, there are a few general studies on oil situation and energy analysis in those countries.

For Saudi Arabia, most of the studies in oil and other fields have been carried out by Saudi Arabian students seeking graduate work in the West.

Shams (1984) developed a doctoral dissertation to allocate the Saudi oil production by pursuing a conservation policy subject to two constraints: the relationship between Saudi Arabia and the other OPEC members, and the involvement of the oil-consuming countries in the present oil crises.

The analysis was directed to the theory of exhaustible resources and its validity to the Saudi Arabian oil situation. The Saudi planners are assumed to maximize the present value of the benefits minus cost over all relevant periods subject to oil production level in those periods, the initial oil reserve, and the total oil reserve. Although he did not present an empirical result for Saudi Arabia, his recommendations are as follow:

(1) Saudi Arabia should reduce prices of crude oil and increase production in order to gain a larger share of the world oil market. This would move Saudi Arabia toward the optimal allocation path of oil resources over time.

(2) For OPEC to succeed (Saudi Arabia is a member of OPEC) a long-run future policy aimed at decreasing the increasing elasticity of demand for oil is vitally required. It is not clear how this recommendation can be approached.

(3) Economic development plans for OPEC members should be slowed down to keep pace with the lower expected decrease in oil revenues.

His conclusion is that Saudi Arabia was not pursuing an oil-conservation policy based on appropriate rates of discount. The social rate of return on domestic investment was never considered as a measure for intertemporal allocation of oil revenues. He therefore recommended that Saudi Arabia should use the domestic rate of return on investment in the non-oil sectors as a social rate of discount after comparing it with the rate of return on foreign investment and adjusting both rates for risk and uncertainty.

El Shayal and Al-Zakri (1981) discussed the future energy demand situation in Saudi Arabia. They pointed out that the Kingdom's consumption of energy is increasing over time and that oil availability will become lower and lower over time. They pointed out that by the year 2000, energy consumption in the Kingdom may reach 2 to 3 million barrels per day, the larger part of this being consumed by the transportation and utilities sectors. They summarize the Kingdom's energy situation by the year 2000 as follows:

(1) Oil reserves will be low.

(2) The availability of oil and natural gas for utilities and petrochemicals industry will be limited and very expensive.

They pointed out that by the year 2000 electricity will be expensive and an advanced introduction of technology and other sources of energy will be helpful in lowering dependence on oil. To reduce the future energy problem, they recommend the following:

(1) Stockpiling uranium for future use.

(2) Expanding the electric energy grid in the Kingdom.

(3) Acquiring experience and facilities for enriching and processing of

nuclear fuel.

(4) Preparing an energy conservation plan for all sectors of the Kingdom.

(5) Planning an information campaign to inform the Saudi public about nuclear energy.

Al-Janabi (1979) estimated and projected the demand for aggregate petroleum refined products in OPEC member countries as a function of real GDP and growth rate. He also calculated the income elasticity for the aggregate petroleum refined products in OPEC member countries. For Saudi Arabia, his demand projection for 1985, 1987, 1990 are 1,229,100, 1,981,500, and 4,056,100 barrels a day, respectively. The estimated income elasticity for Saudi Arabian aggregate refined products consumption is 2.63.

Carol Dahl (1982) estimated the demand elasticities for gasoline, using a dynamic formulation of the flow adjustment type model as follows:

$$\ln QGAS_t = a + b \ln PGAS_t + c \ln GDP + d \ln VEH_t + e \ln QGAS_{t-1} + n_t$$

where:

QGAS : per capita gasoline consumption.

GDP : per capita income.

VEH : per capita stock of vehicles.

PGAS : price of gasoline deflated by CPI.

b, c, d : are estimates of short-run elasticities with respect to price, income and vehicle.

In estimating the above equations, she used cross-section time-series data for 1970-1978 from forty-one countries, Saudi Arabia being one of them.

It was found that Saudi Arabia, with a low gasoline price, had significantly different coefficients from the other countries at the 5 percent significant level. Venezuela, with its exceptionally low prices, was significantly different from

Saudi Arabia and Bolivia. The short-run demand elasticities for all countries in the sample are -.13 for price, .06 for income, and .11 for vehicle. The long-run demand elasticities for all countries in the sample are .76 for price, .35 for income and .64 for vehicle stock. When the three countries low prices are excluded, the short-run elasticities are -.20 for price, .11 for income, and .12 for vehicle. The long-run elasticities in this case are -.98 for price, .50 for income, and .57 for vehicle.

In two articles, one by Fesharaki, Totto, Johnson and Isaak (1982) and the other by Totto and Johnston (1983), the domestic oil demand and forecasting for OPEC countries were presented. In the estimation of the demand function they used linear relationship, semi-log function, or the familiar double log function. They estimated per capita consumption of some fuels as a function of price and gross domestic product in terms of the U.S. dollar. The estimation covers the period 1970-1979, which is divided into two periods; 1970-1975 and 1976-1979. The results for Saudi Arabia are presented in Table III.

In evaluating these two studies and the related ones, some critical points that make the results of these studies less acceptable are as follows:

(1) The first point is related to the size of the sample used in the estimation. As is shown above, the observation sample is very small. From the econometric point of view, the larger the sample the more efficient the estimation and forecasting results. Although our observation sample is small, it contains a large sample size relative to those two studies. Our sample size will give more efficient estimation and forecasting results.

(2) The second critical point is related to the data and its sources. Price and consumption data are available from different sources, such as

TABLE III*

SUMMARY OF FESHARAKI, TOTTO, JOHNSON AND ISAAK STUDIES

	1970-75	1975-79	1976-79	1970-79
Gasoline				
Income Elasticity	.88	--	1.02	--
Price Elasticity	--	--	--	-.09
Kerosene				
Income Elasticity	--	--	--	-.11
Price Elasticity	--	--	--	-.95
Diesel				
Income Elasticity	--	1.34	--	--
Price Elasticity	--	-.16	--	--
Residual				
Income Elasticity	1.07	--	1.05	--
Price Elasticity	--	--	--	-.52

* The results shown in this table are presented in both articles.

the United Nations Energy Statistics, International Energy Annual, and OPEC Statistical Bulletin. Data in these publications are contradictory and not clear, even within one individual publication. Differences and ambiguous figures are easily found among these publications. We feel that the use of any of these publications or a combination of them will create data error that will make estimation and forecasting ambiguous. The use of the original data source for product price will avoid any contradictory statistical publication.

(3) The third point is related to conversion. The conversion from Saudi currency to the U.S. dollar for prices and income will result in some calculation and structural errors. This is due to which exchange rate is used, i.e., mid-year exchange rate, average exchange rate or any other. On the other hand, a quantity error may be made when converting from barrel to metric tons and vice-versa. In our study the prices and the income are in Saudi Arabian currencies. Also the actual unit of measurement in Saudi publications are being used.

Evaluation

This chapter reviewed the major theoretical and empirical models and their corresponding works in the field of the demand for petroleum refined products. The consumer demand approach was adapted by most of the literature. According to this approach, the quantity of a good consumed is a function of its own price, consumer income, prices of substitutes, and other variables.

The literature shows that the quantity of the energy product consumed regressed on its price and income. In their demand functions some studies included the price of substitutes, number of vehicles, temperatures and/or other variables. With few exceptions, the results of some of these regressions are reported without mentioning the magnitude of the Durbin-Watson test statistics. This silence is noticeable since one is usually concerned about autocorrelation in the use of time-series data. The multicolinearity problem is barely discussed in many studies. With multicolinearity, a significant test is difficult or impossible to interpret. In some of the literature the wrong sign or the insignificance of some coefficients may be attributed to the presence of multicolinearity among the independent variables.

CHAPTER III

ECONOMIC GROWTH, OIL, AND ENERGY IN SAUDI ARABIA

Saudi Arabia has undergone a remarkable economic and social transformation during the last fifteen years. Real GDP per capita grew rapidly, making the Kingdom one of the fastest growing economies in the world and moving it out of the World Bank classification of a poor country up into the group of rich ones. It is apparent that much of this growth has directly or indirectly been related to the production and export of oil. Some issues regarding this non-renewable resource should be analyzed and presented in a detailed framework so that an optimal path for future oil production may be formulated. The main issue that we are analyzing in this dissertation is the consumption of petroleum refined products in Saudi Arabia. According to the United Nations Energy Statistics, Saudi Arabia was one of the top countries in energy consumption per capita in 1980.[1]

Oil and Growth in Saudi Arabia

The petroleum sector in Saudi Arabia is the single most important factor in the Saudi economy. Up to now the petroleum sector has contributed the largest percentage of the total gross domestic product. As shown in Table IV,

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[1]United Nation, 1982 United Nations Energy Statistics, (New York, 1985), various pages.

TABLE IV

PERCENTAGE SHARE OF THE OIL AND NON-OIL SECTORS IN GDP

	First Plan	Second Plan					Third Plan			
	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
GDP	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Oil Sector	59.9	55.8	55.0	51.5	49.4	48.6	46.5	41.5	29.8	27.0
Non-oil Sector	40.1	44.2	45.0	48.5	50.6	51.4	53.5	58.5	70.2	73.0
a) Private	26.8	29.0	30.1	32.5	33.6	34.5	35.6	39.5	49.2	52.4
b) Government	13.3	15.2	14.9	16.0	17.0	16.9	17.9	19.0	21.0	20.6
		Annual Growth Rates								
GDP	0.9	8.6	14.8	6.2	6.6	10.2	8.0	1.7	-10.9	0.9
Oil Sector	-5.8	1.1	13.2	-0.5	2.3	8.5	3.3	-9.2	-36.1	-8.7
Non-oil Sector	13.0	19.8	16.9	14.5	11.2	11.8	12.5	11.1	7.1	5.0
a) Private	7.7	17.8	18.9	15.0	10.2	12.7	11.8	12.6	11.0	7.7
b) Government	25.3	23.9	12.9	13.5	13.2	10.1	13.8	8.1	-1.2	-1.4

Source: Saudi Arabian Monetary Agency. Annual Report: 1984. Riyadh, Saudi Arabia, 1984.

in 1974 the oil sector contributed 59.9 percent of the total GDP. In 1983, the oil sector share in the GDP dropped to only 27 percent. The non-oil sectors share in the GDP grew until it constituted almost 73 percent of the GDP in 1983. However, the revenue from the oil sector has been increasing over time, especially after the 1973 and 1979 oil price increases. As shown in Table V, the revenues increased from 5.24 billion dollars in 1964 to 113.2 billion dollars in 1981. The main reasons for this huge revenue were the price hikes in 1973 and 1979 and the high Saudi oil production level. The growth of the other sectors of the economy is now largely dependent on the growth of the oil sector. Budget formulation and allocation between the economic sectors depends mainly on these oil revenues. Without these funds, budget allocation between the economic sectors is very limited and constrained. Investment in major development programs for hydrocarbon-based industries in Saudi Arabia for the period 1975-1985 was planned to be 170 billion Saudi Riyal.[2] This, of course, depended on the huge revenues that the Kingdom obtained from oil.

Since 1938, when oil production commenced, the growth in crude petroleum production has been determined largely by several exogenous factors:

(1) War in the Middle East appears to be one of the important factors contributing to the increases and decreases in total Saudi Arabian oil production.

(2) World oil demand and supply may be considered the most important factor. As world demand increases (decreases), the growth rate of

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[2]Ministry of Planning. Second Development Plan: 1975-1980, (Riyadh, Saudi Arabia, 1975), p. 182.

TABLE V

REVENUES FROM SAUDI ARABIAN OIL
(MILLION U.S. DOLLARS)

Year	Revenues
1964	523
1965	664
1966	790
1967	904
1968	926
1969	949
1970	1,214
1971	1,885
1972	2,745
1973	4,340
1974	22,574
1975	25,676
1976	30,755
1977	36,540
1978	32,234
1979	57,522
1980	102,212
1981	113,200
1982	76,000
1983	46,100
1984	43,700

Source: Organization of Petroleum Exporting Countries. Annual Statistical Bulletin: 1984. Vienna, 1985.

Saudi oil production increases (decreases). An increase or a decrease in world oil supply appears to have the same impact as decrease or increase in world oil demand. Saudi Arabia, with a high production capacity, can help ease a possible shortage in the oil market. In late 1980, when the war between Iraq and Iran started, Saudi Arabia increased its oil production by more than one million barrels daily to substitute partially for the decline in both Iraqi and Iranian oil production.

(3) The political factor has a very important role in oil production. The Arab petroleum producing and exporting countries may use their oil production policy to gain support in one area or another. The 1973 oil embargo on the West by Arab countries is a clear example in this case.

Table VI shows the Saudi Arabian oil production patterns since 1938. It can be shown that in 1966 oil production rose by 18 percent over the previous year; in 1983 it declined by 30 percent below the previous year. Over the last four decades of oil production, Saudi accumulative production reached 51.4 billion barrels. If the same patterns of production in Table VI appear in the future, the Saudi estimated reserve at the end of 1984 of 171 billion will be enough for more than 60 years.

With a huge oil revenue as shown in Table V and a huge oil reserve of 171 billion barrels in 1984, economic growth has been accelerated in Saudi Arabia and will continue to increase in the future. In spite of managerial and several other problems, per capita income increased, capital infrastructure was modernized, new industrial sites were created and health and social services were significantly expanded. More specifically, the Kingdom has undergone a remarkable economic and social transformation during the last fifteen years.

TABLE VI

SAUDI ARABIAN CRUDE OIL PRODUCTION
(THOUSAND BARRELS)

Year	Daily Average	Cumulative	Annual % Change in Daily Production
1938	1.4	495	
1939	10.8	4,429	671.4
1940	13.9	9,504	28.7
1941	11.8	13,814	-15.1
1942	12.4	18,344	5.1
1943	13.3	23,212	7.3
1944	21.3	31,006	60.2
1945	58.4	52,317	174.2
1946	164.2	112,261	181.1
1947	246.2	202,113	49.9
1948	390.3	344,966	58.5
1949	476.7	518,975	22.1
1950	546.7	718,522	14.7
1951	761.5	966,484	39.3
1952	824.8	1,298,345	8.3
1953	844.6	1,616,639	2.4
1954	961.8	1,957,683	13.9
1955	976.6	2,314,132	1.5
1956	1002.8	2,681,169	2.7
1957	1030.8	3,057,423	2.8
1958	1058.5	3,443,766	2.7
1959	1152.7	3,864,499	8.9
1960	1313.5	4,345,233	13.9
1961	1480.1	4,885,470	12.7
1962	1642.9	5,485,136	11.0
1963	1786.0	6,137,026	8.7
1964	1896.5	6,831,155	6.2
1965	2205.3	7,636,091	16.3
1966	2601.8	8,585,751	18.0
1967	2805.0	9,609,591	7.8
1968	3042.9	10,723,308	8.5
1969	3216.2	11,897,204	5.7
1970	3799.1	13,283,863	18.1
1971	4768.9	15,024,496	25.5
1972	6016.3	17,226,458	26.2
1973	7596.2	19,999,063	26.3
1974	8479.7	23,094,151	11.6
1975	7075.4	25,676,686	-16.6

TABLE VI (Continued)

Year	Daily Average	Cumulative	Annual % Change in Daily Production
1976	8577.2	28,815,958	21.2
1977	9199.9	32,173,918	7.3
1978	8301.1	35,203,823	-9.8
1979	9532.6	38,683,211	14.8
1980	9900.5	42,306,794	3.9
1981	9808.0	45,886,714	-.9
1982	6483.0	48,253,009	-.33
1983	4539.4	49,909,890	-30.6
1984	4079.1	51,402,840	-10.1

Source: Organization of Petroleum Exporting Countries, Annual Statistical Bulletin: 1984, Viena, 1985.

Unfortunately, these recent progresses in Saudi Arabia are closely tied to a single sector of the economy which depends on one non-renewable resource. This resource is the main financing source for the needs of the whole nation.

Over the past fifteen years, Saudi Arabia experienced an economic growth that has exceeded original expectations. There were substantial fluctuations in the growth rate during this period of time. The increase in GDP over the first and second plans averaged 10.6 percent.[3] The third development plan is more ambitious and its achievement is not at hand.[4]

As output and income grow, a substantial change in the economic structure results, with industrialization increasing its share at the expense of other sectors. The share of agriculture sector decreases over time due to oil discovery and recent industrialization policy. This industrialization has been sparked by an investment direction providing substantial incentives to increase oil export in order to earn more foreign exchange for financing the different economic activities. Although this policy was successful in increasing industrial output, it has some disadvantages:

(1) It increases the cost to the Saudi society. Increasing oil production will hasten the depletion of this resource.

(2) It directed the Saudi economy toward capital-intensive techniques and hence capital intensive industries. This will require more energy consumption in the future as well as reduce the country's security.

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[3]Ministry of Planning, Achievement of the First and Second Development Plans, (Riyadh, Saudi Arabia, 1981), p. 4.

[4]For detail data on economic development, one may be referred to the four Saudi Arabian development plans and various issues of SAMA Annual Reports.

In Saudi Arabia, although private enterprises were encouraged, the government relied more on the control and ownership of the means of production, distribution, and many economic activities as an industrialization strategy. In recent years, the government created large scale industries and encouraged several medium-size agricultural firms.

Currently, the major sources of energy in Saudi Arabia are: oil, electricity, and natural gas. Oil is the leading source in the Kingdom followed by electricity and natural gas. However, electricity and natural gas are increasing in importance and the prospects for these are bright as more distribution channels and more alternative usages become available.

Electricity consumption in Saudi Arabia has become one of the most reliable indicators for industrial growth. Electricity is a feasible source of energy for small as well as large scale industrialization. In recent years, one of the major tasks in the Kingdom is to establish electric power facilities that can provide the needed power for industrial and household purposes.

Petroleum has played an important and a growing role as an energy source in the Kingdom; it is the primary fuel for transportation, power generation, household usage and industrial inputs. The drastic decrease in the price of oil has brought about a significant change in domestic oil policies in the Kingdom. In 1984, domestic oil prices for all refined products increased by more than double. If the oil situation at the present continues to be the same for the next few years, energy prices in the domestic market are expected to increase.

The use of natural gas in Saudi Arabia has been expanded. While it was used for household cooking prior to 1980, it is now used as input for the petrochemical industries with some exceptions.

Saudi Arabian Economic Resources: Problems and Prospects

It is understood that Saudi Arabia is endowed with oil and gas which play a significant role in its national development. This commodity is exported to yield foreign exchange earnings. The higher the oil prices, the more flexible it becomes to mobilize this fund for different areas in the economy.

The Saudi government policy was directed toward efforts to support the agricultural sector and to develop the basic industrial facilities. During the last few years, some products, such as fertilizer, wheat, metal, cement and petrochemicals, have been produced in sufficient quantity to meet not only domestic needs but also to be exported. This, of course, not only saves foreign exchange for import but also increases revenues or receipts and the countries security. On the other hand, the large land mass of the Kingdom creates a potential for non-oil mineral development, but the prospects for this at present are uncertain.

During the last few years, oil production in the Kingdom is stagnating and growing slowly due to structural changes in the international demand for oil. Oil prices have also been declining and are very difficult to predict. Much depends on international, political and economic developments over which Saudi Arabia has little or no control.

Oil export from Saudi Arabia is linked to the Kingdom's development and expenditures and is affected by different political and economic factors. The Saudi plan is designed to fulfill the government needs for revenues. An analysis of oil reserves, production, consumption and exports in the past and present may be helpful in determining such a plan. It is understood that domestic consumption of crude oil and petroleum refined products is increasing. If this trend continues to expand, oil export volume may decrease. Therefore, there may be a need to moderate domestic oil consumption growth through a combination of resource substitution and price increases.

The prospects for liquified natural gas is favorable and encouraging. It has already been put to better use as a resource of energy for domestic use and for export. An expansion of domestic distribution facilities for natural gas is underway. On the other hand, natural gas is the main input for different industries which are being designed for domestic consumption and/or export.

Since the discovery of oil, oil revenues continue to increase as more exploration and exports are encountered. Since not all Saudi Arabian territory has been geologically surveyed, it is hoped that the remaining area could contribute to an increase in oil reserves. However, if known oil reserves stay as they are now, and production continues at about 7 million barrels a day, the reserve will gradually be exhausted by the year 2053. Sooner or later, alternative energy sources should be developed in order to reduce oil consumption domestically; oil can then be directed toward export to earn foreign exchange for the financing of the Kingdom's development programs. It has been suggested by one expert that oil production should be increased to its 1980 level of 9 million barrels a day.[5] If this strategy is employed, oil reserves will be exhausted before the expected date.

To analyze the possibilities of reducing oil consumption, one has to consider the patterns of energy production and consumption. Table VII shows the patterns of energy consumption for the 1979 period. As is shown, energy consumption is made of petroleum, natural gas, and electricity. The share of

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[5]Personal conversation with one ARAMCO oil expert official in summer 1985.

TABLE VII

ENERGY CONSUMPTION IN SAUDI ARABIA 1979
(THOUSAND OF OIL BARRELS EQUIVALENT)

Total	22,039
Thermal (electricity)	3,358
Natural Gas	2,100
Petroleum Products	16,581

Source: "Oil and Energy in the Arab World," Middle East Economic Survey, Supplement, Vol. 25, No. 27, (April 19, 1982), pp. 1-14.

petroleum refined products in this is almost 75 percent, followed by electricity at 15 percent and natural gas at almost 10 percent.

Table VIII shows the consumption of energy by various sectors of the Saudi economy. According to this table, the industrial sector appears to be the largest in energy consumption, using almost 37 percent. The transportation and energy sectors each consume 28 percent, followed by 2 percent for the commercial and residential sector, 1 percent for the agricultural sector, and the remainder for the others. As shown in the table, most of the energy consumption was in the form of oil and natural gas with a high percentage of oil and mainly oil refined products.

As for natural gas, the reserves in 1984 were estimated to be 3,608 trillion cubic meters. Production in 1984 was estimated at 29,050 million cubic meters. As shown in Table IX, proven natural gas reserves made Saudi Arabia one of the ten top countries in natural gas reserves. A considerable amount of foreign exchange is expected from this source, either directly or indirectly: directly, from exporting this commodity abroad; indirectly, from domestic consumption related to substitution possibilities and market sales.

The theoretical potential of the hydropower resources in Saudi Arabia was estimated to be 14,699 MW in 1984 per annum. The total installed hydropower capacity in 1983 is 10,704 MW. Bearing in mind the great value of oil conservation, it will be necessary to use hydropower resources as well as nuclear and solar energy resources in the future. In the fourth development plan, the government has projected achieving a target of 20,050 MW installed hydropower capacity in the year 1990.

TABLE VIII

ENERGY CONSUMPTION IN SAUDI ARABIA BY THE ECONOMIC SECTORS, 1980 (BARREL)

Sectors	Quantity
1. Commercial and Residential Sectors (total)	4,586,000
a. Kerosene	1,266,000
b. Liquid gas	3,320,000
2. Industrial sector (total)	78,560,694
a. Desalination (total)	6,082,500
-dry gas	750,000
-diesel	277,500
-fuel oil	5,055,000
b. Industrial complexes (total) gas	25,778,194
c. Construction (total) diesel	42,600,000
d. Petroleum Industry (total)	42,600,000
-gas	34,000,000
-crude oil	6,200,000
-diesel	1,000,000
-fuel oil	1,400,000
e. Cement and other industry	4,100,000
3. Electricity Sector (total)	59,500,000
-dry gas	34,000,000
-diesel	16,100,000
-crude oil	9,400,000
4. Transportation Sector (total)	60,468,000
a. Small cars	31,868,000
b. Trucks (diesel)	14,000,000
c. Airplanes	11,600,000
d. Saudi ships	3,000,000
5. Agricultural Sector - Total diesel	2,300,000
6. Asphalt	3,100,000
7. Other Products/Naphta	3,400,000
Total in Barrels	211,914,694
Average daily (B/D)	580,588

Source: "Oil and Energy in the Arab World," Middle East Economic Survey, Supplement, Vol. 25, No. 27, (April 19, 1982), pp. 1-14.

TABLE IX

PROVEN NATURAL GAS RESERVES
(THOUSAND MILLION CUBIC METERS)

Year	Quantity
1971	1,295.1
1972	1,242.6
1973	1,270.1
1974	1,356.2
1975	2,447.1
1976	1,502.6
1977	2,002.6
1978	2,204.9
1979	2,189.7
1980	3,183.2
1981	3,346.1
1982	3,432.2
1983	3,544.0
1984	3,608.0

Source: Organization of Petroleum Exporting Countries. Annual Statistical Bulletins: 1980 and 1984. Vienna 1981 and 1982.

The Importance of Oil and Gas to the Saudi Economy

Saudi Arabia is endowed with one major non-renewable resource--oil. Since its discovery and production, which started in 1938, oil has produced relatively large export earnings for Saudi Arabia in the form of foreign exchange. From Table X, one can see the value of total export and share of oil. As is shown, oil is the major export product. The dependency upon oil makes the country vulnerable in its economic development effort. Further development of other resources should be encouraged to lessen the burden on petroleum in the Saudi Arabian development. Tables XI and XII stress the importance of oil and gas and other resources to the Saudi Arabian economy. The balance of payments showed a favorable condition in terms of increases in the international reserves. With oil export, the balance of trade indicated a surplus. Without oil revenues, deficits that occurred several times would be even larger.

Saudi Arabia's imports consisted of consumption goods, raw materials and capital goods. The patterns of import fluctuated over time. During the 1960's, consumption goods were given higher priority while in the 1970's and early 1980's, a diversification policy of imports was followed. Starting in 1983, several government policies were implemented to limit import due to the oil price decreases.

It is understood that the policy of the Saudi government concerning the balance of payment is to increase export earnings in order to finance the imports necessary to induce productive activities and to meet domestic consumption. It also aims to expand economic development as well as saving foreign exchange through import substitution and the use of foreign resources.

TABLE X

SAUDI ARABIA VALUE OF EXPORT, PETROLEUM EXPORT AND THE SHARE OF OIL EXPORT IN TOTAL EXPORT (MILLION IN U.S. $)

Year	Total Value of Export	Petroleum Export	Oil Export as a % of Total Export
1964	1,091	1,089	99.8
1965	1,269	1,264	99.6
1966	1,496	1,491	99.7
1967	1,600	1,596	99.7
1968	1,780	1,776	99.8
1969	1,871	1,864	99.6
1970	2,353	2,347	99.7
1971	3,477	3,470	99.8
1972	4,560	4,546	99.7
1973	7,802	7,802	100.0
1974	31,248	31,166	99.7
1975	27,996	27,880	99.6
1976	36,431	36,309	99.7
1977	41,222	41,125	99.8
1978	37,843	37,843	100.0
1979	57,512	57,512	100.0
1980	102,259	102,259	100.0
1981	113,406	113,406	100.0
1982	76,247	76,247	100.0
1983	47,814	47,814	100.0
1984	46,844	46,844	100.0

Source: Organization of Petroleum Exporting Countries. Annual Statistical Bulletin: 1984. Vienna, 1985.

TABLE XI

ESTIMATED CURRENT ACCOUNT BALANCE
(MILLION U.S. $)

Year	Balance
1964	161
1965	128
1966	140
1967	98
1968	-92
1969	-86
1970	71
1971	972
1972	2,089
1973	2,520
1974	23,025
1975	17,512
1976	17,683
1977	15,891
1978	1,689
1979	14,669
1980	46,904
1981	44,064
1982	-1,100
1983	-18,433
1984	-13,220

Source: Organization of Petroleum Exporting Countries. Annual Statistical Bulletin: 1984. Vienna, 1985.

TABLE XII

BALANCE OF PAYMENTS ESTIMATES
(MILLION OF SAUDI RIYALS)*

Classification	1981	1982	1983	1984
1. Merchandise trade, f.o.b.	277,174	135,175	43,110	31,343
a) Oil exports (excluding bunker oil)	375,320	249,978	154,305	127,518
b) Other exports of	2,954	3,278	3,565	4,450
which re-exports	(2,413)	(2,695)	(2,619)	(2,505)
c) Imports	-101,000	-118,081	-114,760	-100,625
2. Services and transfers	-132,532	-109,220	-98,616	-98,451
a) Receipts	54,916	64,967	73,530	61,937
i) Investment income	37,059	48,197	54,819	47,096
ii) Oil sector (bunker oil)	1,996	1,124	574	331
iii) Other	15,861	15,646	18,137	14,510
b) Payments	-187,448	-174,187	-172,146	-160,388
i) Freight and insurance	-18,198	-21,254	-20,657	-18,112
ii) Oil sector investment income	-32,470	-21,291	-14,818	-12,682
iii) Other private services	-38,747	-38,268	-32,788	-32,549
iv) Other Government services	-84,168	-75,044	-85,797	-78,422
v) Private transfers	-13,865	-18,330	-18,086	-18,623
3. Capital Movements and Reserves	-144,642	-25,955	+55,506	+67,108
a) Oil sector & other capital transactions (net)	+21,811	+38,153	+17,409	+18,419
b) Others	-166,453	-64,108	+38,097	+48,689
4. Exchange rates				
a) End of year	3,4150	3,4350	3,4950	3,5750
b) Weighted average	3,3826	3,4274	3,4549	3,5238

Source: Saudi Arabian Monetary Agency. Annual Report: 1985, Riyadh, Saudi Arabia, 1985.
*One U.S. dollar = 3.75 Saudi Riyals.

This policy is in fact a part of the Saudi Arabian development plans that have been implemented by the government since 1970.

Returning to the justification of the importance of oil and gas and other resources to the Saudi economy, one can see that the actual government revenues and expenditures assumed to be balanced showed a surplus, especially in the 1970's and the early 1980's. In 1974, there was a surplus amounting to 23 billion dollars. Table XI shows the Saudi Arabian balance of payment surpluses or deficit over the period 1964-1984. If one analyzes the situation further, a deficit could have occurred had the export oil price declined to a very low level. This is in fact what has happened since 1984, particularly at the beginning of 1986. The 1986-87 Saudi Arabian budget has been postponed several times and the government operated on a monthly basis, without an annual budget. The main reason for this is the sharp decline in oil prices from 34.0 dollars a barrel to a level below 10.0 dollars a barrel.

Saudi Arabia cannot depend upon oil and gas in its development forever. Utilization of other resources and sectors of the economy would free the country from its dependency on these minerals. Since the agricultural sector cannot be expanded rapidly, further development of the manufacturing sector is a necessity for future export. In the development planning, the Saudi government is following a diversification strategy. However, special attention was given to basic manufacturing industries that used capital-intensive methods and techniques. Together with this, the government implemented educational and training programs, increased rural development activities, improved the infrastructure, improved the health care institution and improved social life for the whole society.

Energy Supply in Saudi Arabia

Saudi Arabia's dependence on petroleum fuel is largely a result of its crude oil reserves and its historical role as an oil exporter. The search for oil in Saudi Arabia began in 1933, with the first commercial oil commencing operations in 1938. With the exception of temporary decline in production due to hostilities during World War II, crude oil production in Saudi Arabia grew steadily until it reached a peak of 9.9 million barrels daily in 1980. This growth is documented in Table VI and is illustrated in Figure 1. Since this time, production has been fluctuating. The major decline occurred in 1982 and was caused by the gradual decline in the world demand for oil brought about by recession conditions as well as production quotas imposed by OPEC on member nations.

The commercial energy supply in Saudi Arabia began with Aramco and the discovery of oil in 1933. In this year, a concession agreement between the Saudi government and the Standard Oil Company of California was signed for the purpose of oil exploration and production.[6] Following this agreement, Aramco held major responsibility for oil activities in the Kingdom. Soon after World War II, an oil refinery with a possible capacity expansion of up to 415,000 barrels per day was built in Ras Tanura. Recently, six additional refineries have been constructed and are currently operating in different locations throughout the Kingdom.

The domestic energy supply, which is mainly oil, may be affected by one or a combination of the following factors:

(1) Saudi Arabian crude oil production level.

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[6]Arabian American Oil Co. <u>ARAMCO Handbook and Oil in the Middle East</u>. (Dhahran, Aramco, 1968), p. 112.

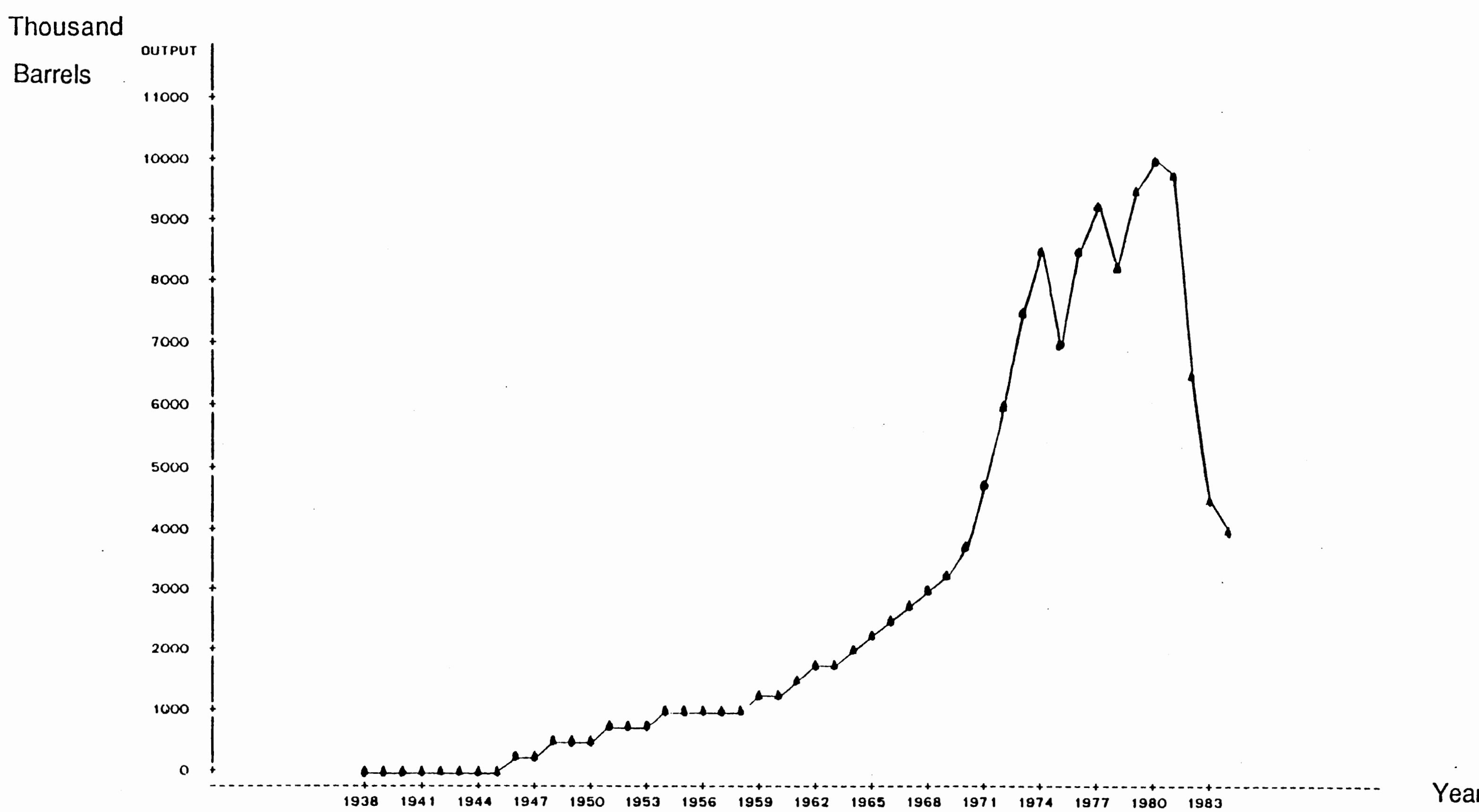

Figure 1. Average Oil Production Over Time

(2) Saudi Arabian oil export policy.

(3) Domestic consumption of crude oil.

(4) The demand for domestic inventory.

(5) Expected world price for crude oil and refined products.

(6) Saudi Arabian economic development and growth.

The supply of petroleum products in Saudi Arabia is governed by the processing configurations of the domestic refineries and the types of petroleum products consumed. A total of seven refineries are currently operating. The installed technical capacity of these refineries was 1,298,000 barrels per day in 1984. Table XIII shows the refining capacity expansion since 1964. Currently, over 40 percent of the refining capacity comes from the Ras Tanura refinery as shown in Table XIV. These refineries are designed to produce petroleum products for domestic and foreign markets. Table XV shows the various refinery classifications. The Aramco refinery and Khafji refinery contributes to both domestic consumption and export. In addition to these, there is the Mina-Saud refinery located in the Natural-Zone which could also be considered an export refinery.

The supply and export of petroleum products during the period 1964-1984 is presented in Table XVI. This table highlights the trend patterns in petroleum products. The major trend is the increase in the use of domestic refinery output for national consumption. Although refinery output during the last fifteen years increased rapidly from 617,300 barrels daily in 1970 to 878,000 barrels daily in 1982, the percentage of this output used for domestic consumption rose from 43 percent in 1970 to 56 percent in 1982.

In many countries, as well as Saudi Arabia, crude oil is used to produce different petroleum products. Throughout the refining process different products are derived. Of these, Saudi Arabia produces the following: aviation

TABLE XIII

REFINING CAPACITY IN SAUDI ARABIA
(THOUSAND BARREL DAILY)

Year	Quantity
1964	257.5
1965	302.5
1966	335.0
1967	335.0
1968	347.0
1969	347.0
1970	676.0
1971	676.0
1972	676.0
1973	676.0
1974	676.0
1975	703.0
1976	703.0
1977	703.0
1978	758.0
1979	758.0
1980	878.0
1981	878.0
1982	878.0
1983	1,048.0
1984	1,298.0

Source: Organization of Petroleum Exporting Countries. Annual Statistical Bulletin: 1984. Vienna, 1985.

TABLE XIV

REFINERY CAPACITY IN SAUDI ARABIA
(THOUSAND BARREL DAILY)

Name	Location	1980	1981	1982	1983	1984
ARAMCO	Ras Tanura	563.0	563.0	563.0	563.0	563.0
JORC	Jeddah	105.0	105.0	105.0	105.0	105.0
RORC	Riyadh	130.0	130.0	130.0	130.0	130.0
Getty	Mina-Saud	50.0	50.0	50.0	50.0	50.0
AOC	Khafji	30.0	30.0	30.0	30.0	30.0
Petromin	Yanbu				170.0	170.0
Petromin/Shell	Yanbu					250.0
TOTAL		878.0	878.0	878.0	1,048.0	1,298.0

Source: Organization of Petroleum Exporting Countries. Annual Stastistical Bulletin: 1984. Vienna, 1985.

TABLE XV

REFINERY CLASSIFICATION

Domestic Refinery	Export Refinery
1. ARAMCO, Ras Tanura	1. Petromin/Petrola (Rabigh)
2. Jeddah O.R.C.	2. Petromin/Mobil (Yanbu)
3. Riyadh O.R.C.	3. Petromin/Shell (Jubail)
4. Petromin Yanbu	4. Petromin/Texaco-Chevron (Jubail)
	5. Petromin/Ashland (Yanbu)

Source: A.H. Taher, "OPEC and Saudi Refining Policy," Middle East Economic Survey, Supplement, Vol. 26, No. 20, (March, 1981), pp. 1-7.

TABLE XVI

PETROLEUM REFINED PRODUCTS PRODUCTION AND EXPORT
(THOUSAND BARRELS DAILY)

Year	Production	Export
1964	267.1	150.2
1965	300.6	179.0
1966	309.2	155.7
1967	366.1	225.8
1968	442.8	290.7
1969	465.6	219.4
1970	617.3	347.0
1971	600.0	294.2
1972	599.2	319.5
1973	644.3	331.7
1974	648.2	321.5
1975	577.6	330.7
1976	703.4	390.0
1977	731.4	341.4
1978	776.9	375.6
1979	834.9	406.8
1980	826.2	406.8
1981	834.2	481.0
1982	851.4	537.6
1983	859.9	495.4
1984	878.0	496.8

Source: Organization of Petroleum Exporting Countries. Annual Statistical Bulletin: 1984. Vienna, 1985.

gasoline, naphtha, diesel oil, fuel oil, asphalt, kerosene, motor gasoline, LPG, jet fuel, butane, and lubricating oil.

Table XVII shows the Saudi Arabian production of refined products. As the table shows, the main products with a high production percentage are naphtha, diesel and fuel oil. On the average, gasoline, kerosene and diesel constitute 13.8, 3.4, and 25.3 percent of the production in 1983, respectively.

Saudi Arabian gas reserves are substantial and exploitation is still in the initial stages. Plans for hydroelectric power expansion and installation, geothermal power, and solar energy have been developed. Limited implementation efforts are underway. However, the potential gains from some of these are slight and contribution is not likely to be felt for a number of years.

Energy Demand in Saudi Arabia

The changing patterns of demand for energy products in Saudi Arabia reflect its status as a rapidly developing nation. Its population is growing while the nation is becoming more urban and cosmopolitan. The average real income is rising, resulting in a higher standard of living. Due to the increased income of the oil sector, the government launched a number of development projects. Literacy levels are rising and more students are securing higher education and training, domestically or abroad. As a result, tastes and preferences have altered and demand for energy products has increased over the last two decades.

The increase in energy consumption and the changes in the patterns of energy consumption in Saudi Arabia could be attributed to the following factors:

(1) Rise in per capita income.

(2) Population growth.

TABLE XVII

PRODUCTION PATTERNS OF PETROLEUM REFINED PRODUCTS IN SAUDI ARABIA (IN THOUSAND U.S. BARRELS)

Year	1967			1968			1969			1970			1971			1972		
Product	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total
LPG[1]	6,683	17.7	5.09	10,643	59.25	6.5	13,259	24.6	7.6	17,017	28.3	7.6	17,895	5.2	8.1	15,855	(11.4)	7.2
Gasoline	5,052	—	4.0	5,668	12.19	3.40	5,817	2.6	3.3	5,765	(.1)	2.7	6,130	6.3	2.7	5,573	(9.1)	2.55
NGL Condensate	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Naphta[2]	17,340	—	13.0	21,047	21.38	12.8	22,336	6.1	12.8	31,777	42.3	14.3	28,245	(11.1)	12.8	32,665	15.6	14.8
Jet Fuel	9,438	(8.0)	7.1	13,177	39.61	8.1	13,962	5.9	8.1	13,785	(.13)	6.2	13,194	(4.3)	6.0	16,303	23.6	7.4
Kerosene	2,885	50.0	2.16	3,195	10.75	1.90	3,370	5.5	1.90	6,861	103.6	3.0	5,311	(22.6)	2.3	4,978	(6.3)	2.3
Diesel Oil	16,322	.17	12.22	19,050	16.71	11.60	19,010	(.2)	11.0	21,629	13.8	9.76	22,905	5.9	10.4	23,458	2.4	10.5
Fuel Oil	74,739	8.0	56.3	88,166	17.97	54.0	90,753	2.9	52.5	126,763	39.7	56.3	124,401	(1.9)	56.7	122,589	(1.6)	55.2
Asphalt	842	28.0	.1	822	(2.4)	.79	891	.80	1.0	1025	15.0	.1	1,118	9.1	1.0	960	(14.0)	.04
Aviation Gasoline	125	—	.01	145	16.0	.01	176	21.4	.01	38	(78.4)	.01	(2)	(105.3)	—	—	—	—
Others	194	(64.5)	.02	1,217	527.32	.9	2,906	138.8	1.7	637	(78.1)	.03	(19)	(103.0)	—	182	1,057.8	.01
TOTAL	133,620	8.5	100%	163,130	22.1	100%	172,480	5.7	100%	225,297	30.6	100%	219,178	(2.7)	100%	222,563	1.5	100%

TABLE XVII (Continued)

Year	1973			1974			1975			1976			1977			1978		
Product	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total
LPG[1]	25,672	61.9	10.8	37,966	47.9	16.0	39,780	4.8	18.9	47,021	18.2	18.3	57,571	22.4	21.6	65,326	13.5	23.0
Gasoline	5,954	6.8	2.4	7,246	21.7	3.1	8,420	16.2	4.0	8,961	6.4	3.5	12,582	40.4	4.7	19,716	56.7	7.0
NGL Condensate	—	—	—	—	—	—	—	—	—	2,338	—	.1	18,591	695.2	7.0	20,612	10.9	7.3
Naphta[2]	42,109	28.9	17.8	40,254	(4.4)	17.0	35,881	(10.9)	17.0	49,737	38.6	19.54	30,419	(38.8)	11.4	27,673	(9.0)	9.8
Jet Fuel	13,166	(19.2)	5.5	7,827	(40.6)	3.2	3,590	(54.1)	1.7	4,346	21.1	1.8	2,054	(52.7)	.76	202	(90.2)	.1
Kerosene	5,549	11.5	2.3	7,431	33.9	3.1	8,781	18.2	4.1	8,535	(2.8)	3.45	8,569	.39	3.2	9,854	15.0	3.4
Diesel Oil	27,247	16.2	11.6	28,110	3.2	11.8	24,941	(11.3)	11.8	26,914	7.9	10.6	32,116	19.3	12.0	37,491	16.7	13.2
Fuel Oil	113,993	(7.0)	48.5	106,352	(6.7)	44.8	86,977	(18.2)	41.3	104,528	20.2	40.7	98,279	(6.0)	36.82	95,423	(2.9)	33.7
Asphalt	1,565	63.0	.1	1,949	24.5	.8	2,465	26.5	1.2	5,049	104.8	2.0	6,676	32.2	2.5	6,178	(7.5)	2.2
Aviation Gasoline	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Others	(83)	(145.6)	—	38	145.8	.02	—	—	—	32	—	.01	117	265.6	.04	1,085	827.4	.3
TOTAL	234,172	5.7	100%	237,173	1.0	100%	210,835	(11.1)	100%	257,461	22.1	100%	266,974	3.7	100%	283,560	6.2	100%

TABLE XVII (Continued)

Year	1979			1980			1981			1982			1983		
Product	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total
LPG[1]	79,523	21.7	26.1	74,865	(5.9)	24.7	69,510	7.2	22.8	57,243	(17.6)	18.4	41,334	(27.8)	12.5
Gasoline	21,316	8.1	7.0	26,814	25.8	8.9	32,272	20.4	10.6	36,669	13.6	11.8	45,924	25.2	13.8
NGL Condensate	32,147	56.0	10.4	32,814	2.1	10.8	27,523	(16.1)	9.1	17,030	(38.1)	5.5	13,630	(20.0)	4.0
Naphta[2]	19,103	(31.0)	6.3	12,688	(33.6)	4.2	11,354	(10.5)	3.7	13,154	15.9	4.2	15,809	20.2	4.7
Jet Fuel	248	22.8	.1	359	44.8	.1	190	(47.1)	.1	1,570	726.3	.5	3,782	140.9	1.1
Kerosene	9,913	.5	3.3	11,691	17.9	3.9	12,020	2.8	3.9	10,244	14.8	3.3	11,429	11.6	3.4
Diesel Oil	34,991	(6.7)	11.5	44,507	27.2	14.7	54,152	21.7	17.8	66,975	23.7	21.6	84,411	26.0	25.3
Fuel Oil	97,997	2.7	32.2	89,003	(9.2)	29.4	85,513	(3.9)	28.1	93,748	9.5	30.2	100,855	7.6	30.2
Asphalt	7,937	28.5	2.6	8,375	5.5	2.8	10,314	23.2	3.4	12,671	28.9	4.1	14,896	17.6	4.5
Aviation Gasoline	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Others	1,560	43.8	.5	1,378	(11.7)	.5	1,652	19.9	.5	1,454	(12.0)	.4	1,714	17.9	.5
TOTAL	304,735	7.5	100%	302,494	(.7)	100%	304,500	.7	100%	310,758	2.1	100%	333,784	7.4	100%

[1]Include NGL from Ras Tanura fractionation plant.
[2]1967-1973 Naphta and NGL Condensate.
% changes calculated by the author.

Source: Ministry of Petroleum and Mineral, Petroleum Statistical Bulletin: 1973, 1977, 1979 and 1983, Riyadh, Saudi Arabia: 1973,1977,1789,1983, Economic Department.

(3) Population migration from rural areas to modern cities.

(4) Education.

(5) High economic growth rate.

(6) Low prices of energy resources.

In Saudi Arabia demand for crude oil stems from the demand for petroleum products which derive their demand from non-oil products and services. Crude oil is consumed directly in only very few cases, one of which is power generation. In these instances, crude oil is used as a form of fuel oil. Furthermore, demand for crude oil is derived from the demand for the following:

(1) Transportation usage, such as gasoline, diesel, kerosene and heavy fuel oil.

(2) Direct energy requirement of those products for industrial use, space heating, and household appliances.

(3) Nonenergy uses, such as chemical feedstock, lubricants, and asphalt.

It has been estimated that by the year 2000, oil energy consumption in Saudi Arabia may reach 2 to 3 million barrels per day. The two major oil energy consuming sectors are transportation and utilities, with a 32 and 29 percent of total energy required in 1980, respectively.[7] Overall, energy consumption will increase as more development projects are implemented and the rate of population growth and per capita income continue to rise.

In Saudi Arabia commercial energy consumption began after the discovery of oil in the late 1930's. Before this, timber was the major energy

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[7]Ministry of Planning. Third Development Plan. Riyadh, (Saudi Arabia, 1980), p. 160.

source in the Kingdom. In a very limited area, kerosene was imported from other countries for lighting and cooking purposes.

The construction of the Ras Tanura refinery after World War II supplied a variety of petroleum refined products for both domestic and export markets. In 1967, Jeddah refinery was built up with a refining capacity of 105,000 barrels a day on the west coast of the Kingdom. In the middle, Riyadh refinery was constructed in early 1970 with a starting capacity of 12,000 barrels daily at that time and an expansion capacity to 130,000 barrels a day in recent years. The construction of the two later refineries eased the demand situation in the western and central regions.

Up to 1966, Aramco used to handle the oil products distribution and marketing. In 1962, the Saudi government established a separate firm called the General Organziation of Petroleum and Minerals, later on referred to as Petromin. The goals of this organization are as follows:[8]

(1) Implement and administer public petroleum and mineral projects in the Kingdom.

(2) Import directly or through agents the country's mineral needs.

(3) Conduct both theoretical and practical studies and research related to petroleum and mineral, as well as actual operations entrusted to it by the government with regard to searching for, producing, refining, selling, transporting, distributing and marketing petroleum and minerals at home and abroad.

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[8]N. Ghorban, "The Changing Role of Petromin," The Arab Gulf Journal, Vol. 1, No.1, Oct. 1981, p. 74.

(4) Cooperate with private companies and organizations undertaking petroleum and mineral activities in order to facilitate prospecting, exploration, exploitation, distribution and marketing.

(5) Establish companies or enterprises at home or abroad, in whose capital the organization will participate with the purpose of engaging in all phases of the petroleum and mineral industry and in industries declining with their derivatives and by-products. The organizations will also engage in the trading in, transportation, sales, distribution and marketing of these minerals and their derivatives and products. It is authorized to hold interest or participate in any manner whatsoever in companies or organization which are engaged in activities similar to its own or which may assist it in the attainment of its objectives, whether in the Kingdom or abroad. It also has the authority, subject to the limitations of the regulation in force, to buy, annex or merge with such companies or organizations. Furthermore the organization has the right to invest in securities pertaining to objectives similar to its own.

Later on, in 1967, Petromin took over the domestic distribution and marketing of petroleum refined products in the Kingdom. Recently, Petromin expanded its distribution and marketing network throughout the Kingdom and abroad. Up to now, Petromin has managed to bring oil products to any customers who required them - anytime, anywhere, all over the Kingdom, regardless of transportation costs and efforts. The growth and patterns in domestic sales of petroleum refined products in Saudi Arabia is illustrated in Table XVIII. As shown in this table, the structure of the demand for petroleum fuels has noticeably changed over time. Motor gasoline, which at one time represented 29.4 percent of total fuel consumption, in 1983 represented 13.4

TABLE XVIII

CONSUMPTION PATTERNS OF PETROLEUM REFINED PRODUCTS AND NATURAL GAS IN SAUDI ARABIA (IN THOUSAND U.S. BARRELS)

Year	1967			1968			1969			1970			1971			1972		
Product	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total
Public[1]																		
Gasoline[2]	3,263	11.1	29.43	3,594	10.1	26.99	3,905	8.6	27.45	4,245	8.7	27.37	4,438	—	16.7	5,060	14.0	16.4
Diesel	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kerosene	878	9.9	7.92	910	3.6	6.83	956	5.0	6.72	972	1.6	6.27	1,043	—	4.0	1,145	9.8	3.7
L.P.G.	257	34.3	2.32	326	26.6	2.45	408	25.2	2.87	489	19.8	3.15	594	—	2.2	745	25.4	2.4
Jet Fuel	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aviation Gasoline	906	24.1	8.17	1,018	12.4	7.65	1,155	13.4	8.12	1,385	19.8	8.93	1,601	—	6.0	2,069	29.2	6.7
Fuel Oil	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Crude Oil	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Asphalt	902	33.1	8.13	886	(1.8)	6.65	855	(3.4)	6.01	992	15.9	6.39	1,077	—	4.0	966	(10.3)	3.1
Lubricants	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Natural Gas	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Industrial Fuel[3]	4,855	13.5	43.78	6,541	34.7	49.12	6,906	5.5	48.54	7,390	7.0	47.64	8,396	—	31.6	10,011	19.2	32.5
Others	28	0.2	0.25	41	44.5	.31	41	0.0	0.29	39	(3.5)	0.25	43	—	0.2	43	0.0	0.2
SUB-TOTAL	11,089	15.0	100	13,316	20.1	100	14.226	6.8	100	15,512	9.0	100	17,192	—	64.7	20,039	16.6	65.0
Oil Industry																		
Fuel Oil	—	—	—	—	—	—	—	—	—	—	—	—	544	—	2.0	732	34.6	2.4
Diesel	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fuel Gas	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
L.P.G.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Natural Gas	—	—	—	—	—	—	—	—	—	—	—	—	8,863	—	33.3	10,045	13.3	32.6
Crude Oil	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SUB-TOTAL	—	—	—	—	—	—	—	—	—	—	—	—	9,407	—	35.3	10,777	14.6	35.0
GRAND TOTAL	11,089	15.0	100	13,316	20.1	100	14,226	6.8	100	15,512	9.0	100	26,599	—	100%	30,816	15.8	100%

TABLE XVIII (Continued)

Year	1973			1974			1975			1976			1977			1978		
Product	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total
Public[1]																		
Gasoline[2]	5,938	17.4	15.7	7,227	22.5	14.7	9,722	33.6	15.2	12,934	33.0	15.9	16,640	28.6	16.7	20,145	21.0	16.5
Diesel	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kerosene	11,172	2.3	3.1	1,246	6.3	2.5	1,285	3.1	2.0	1,214	(5.5)	1.5	1,123	(7.5)	1.2	1,016	(9.5)	6.8
L.P.G.	896	20.3	2.4	1,050	17.2	2.1	1,230	17.1	1.9	1,399	13.7	1.7	1,749	25.0	1.8	3,509	100.6	2.8
Jet Fuel	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aviation Gasoline	2,466	19.2	6.5	3,581	45.2	7.2	4,584	28.0	7.2	5,784	26.2	7.1	7,804	34.9	7.8	8,890	12.8	7.2
Fuel Oil	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Crude Oil	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Asphalt	1,592	64.8	4.2	1,924	20.8	3.9	2,710	40.8	4.2	4,825	78.0	5.9	1,632	(66.2)	1.6	2,151	31.8	1.8
Lubricants	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Natural Gas	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Industrial Fuel[3]	12,774	27.6	33.7	16,865	32.0	34.1	23,166	37.4	36.2	31,565	36.2	38.8	47,607	50.8	47.9	58,077	21.9	47.5
Others	61	41.9	0.2	79	29.5	0.2	101	27.3	0.2	123	21.8	0.2	603	390.2	0.6	772	828.0	0.6
SUB-TOTAL	24,899	24.2	65.8	32,022	28.6	64.7	42,798	33.6	66.9	57,844	35.1	71.1	77,158	33.4	77.6	94,479	22.4	77.2
Oil Industry																		
Fuel Oil	1,152	57.4	3.0	2,287	98.5	4.6	3,028	32.4	4.7	2,710	(10.5)	3.3	1,057	(61.0)	1.1	1,514	43.2	1.2
Diesel	—	—	—	243	—	0.5	415	70.8	0.6	1,257	202.9	1.5	579	(53.9)	0.6	792	36.8	0.6
Fuel Gas	—	—	—	—	—	—	—	—	—	238	—	0.3	591	148.3	0.5	2,637	346.2	2.2
L.P.G.	—	—	—	—	—	—	—	—	—	129	—	0.2	—	—	—	—	—	—
Natural Gas	11,824	17.7	31.2	14,962	26.5	30.2	17,805	19.0	27.8	19,220	7.9	23.6	20,097	4.6	20.2	22,930	13.8	18.8
Crude Oil	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SUB-TOTAL	12,976	20.4	34.2	17,492	34.8	35.3	21,248	21.5	33.1	23,554	10.8	28.9	22,324	(5.2)	22.4	27,873	21.8	22.8
GRAND TOTAL	37,875	22.9	100%	49,514	30.7	100%	64,046	29.3	100%	81,398	27.1	100%	99,482	22.2	100%	122,352	346.2	100%

TABLE XVIII (Continued)

Year	1979			1980			1981			1982			1983		
Product	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total	Quantity	% Change	% of Total
Public[1]															
Gasoline[2]	24,246	21.6	12.14	31,868	31.0	12.55	37,347	25.38	12.46	41,002	.09	12.51	48,195	17.5	13.43
Diesel	44,803	24.7	22.4	59,232	32.2	23.3	72,014	21.58	24.01	79,363	10.2	24.21	87,070	9.71	24.27
Kerosene	938	(7.86)	0.47	526	(43.92)	0.21	518	(1.52)	0.17	1,337	158.10	0.41	1,369	2.39	0.38
L.P.G.	2,717	20.06	1.36	3,328	22.49	1.31	3,770	13.28	1.26	4,588	21.16	1.40	4,412	(3.84)	1.23
Jet Fuel	10,310	17.28	5.16	11,569	12.21	4.56	12,970	12.11	4.33	14,019	8.09	4.28	15,866	13.18	4.42
Aviation Gasoline	16	(20.0)	0.01	16	—	0.01	14	(12.5)	—	223	1,492.86	0.07	16	(92.83)	0.01
Fuel Oil	48,627	38.09	24.35	58,762	20.84	23.15	70,975	20.78	23.66	73,064	2.94	22.29	77,038	5.44	21.48
Crude Oil	8,430	71.52	4.22	12,315	46.09	4.85	15,347	24.62	5.12	20,608	34.28	6.29	29,768	44.45	8.30
Asphalt	2,849	32.57	1.43	3,145	10.39	1.24	5,703	81.34	1.9	8,276	45.11	2.52	9,224	11.46	2.57
Lubricants	134	4.96	0.07	187	39.55	0.07	202	8.02	0.07	14	(93.07)	—	565	3,935.7	0.16
Natural Gas	22,706	72.24	11.37	31,198	37.40	12.29	38,658	23.91	12.89	41,392	7.07	12.63	52,234	26.19	14.56
Industrial Fuel[3]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Others	10	(98.41)	—	6	(40.0)	—	2	(66.67)	—	212	10,500.00	0.06	24	(88.68)	0.01
SUB-TOTAL	165,786	30.69	83.01	212,152	27.97	83.58	257,520	21.39	85.86	284,098	10.32	86.67	325,781	14.67	90.82
Oil Industry															
Fuel Oil	1,781	17.64	0.89	1,362	(23.53)	0.54	2,216	62.7	0.74	2,173	(1.53)	0.66	3,421	57.4	0.95
Diesel	1,141	44.07	0.57	1,039	(8.94)	0.41	1,778	71.13	0.59	2,586	45.44	0.79	2,086	(19.34)	0.58
Fuel Gas	3,649	38.38	1.83	349	(90.44)	0.14	930	166.48	0.31	1,369	74.2	0.42	1,671	22.06	0.47
L.P.G.	9	—	0.01	52	455.56	0.02	152	192.31	0.05	41	(73.03)	0.01	630	1,436.59	0.18
Natural Gas	27,344	13.69	13.69	32,691	19.56	12.88	35,829	9.6	11.95	37,550	4.80	11.45	24,861	(33.79)	6.93
Crude Oil	—	—	—	6,171	—	2.43	1,505	(75.61)	0.50	—	—	—	259	—	0.07
SUB-TOTAL	33,924	6.38	16.99	41,664	22.82	16.42	42,410	1.79	14.14	43,719	3.09	13.33	32,928	(24.68)	9.18
GRAND TOTAL	199,710	25.8	100%	253,816	27.09	100%	299,930	18.17	100%	327,817	9.3	100%	358,709	9.42	100%

[1]For 1967-1970 public data are available only.

[2]Include regular and premium gasoline.

[3]Include diesel, fuel oil, crude oil and natural gas.

Source: Ministry of Petroleum and Mineral. Statistical Bulletins: 1973, 1977, 1979, and 1983, Riyadh, Saudi Arabia: Economic Department, 1973, 1977, 1979, and 1983.

percent of total fuel consumption. Diesel in 1979 represented 22.4 percent and in 1983 represented 24.2 percent of total fuel consumption. The relative share of kerosene in 1967 was 7.9 percent and became, in 1983, 0.38 percent of total fuel consumption.

Petroleum refined products consumption in Saudi Arabia has been increasing rapidly. Refined products consumption during the period 1967-1983 increased from 11,089,000 to 358,709,000 barrels a year. The increasing trend over this period is shown in Table XVIII. This increase is more than thirty times in only two decades. The per capita consumption during the same period increased from 20.16 to 35.9 barrels per person.

As mentioned earlier in Table VII, energy consumption patterns in Saudi Arabia are based on crude petroleum which accounts for more than 75 percent of the total energy consumed in 1979.

Crude petroleum, natural gas, and refined products are either exported or consumed domestically. In 1975, six percent of the crude petroleum produced was consumed domestically while the rest was exported. Natural gas is either reinjected, consumed domestically in the form of liquified natural gas, exported abroad, flared, or in recent years, used as an input to the Petrochemical Industries. In 1975, only 3 percent was consumed domestically. Table XIX shows the patterns of natural gas use in Saudi Arabia. Electricity consumption in Saudi Arabia began with oil exploration and discovery. Since then, electricity consumption has been increasing rapidly. In 1975, the total electric energy sold was 3,760,019 megawatt hours. As shown in Table XX, electricity consumption increased by more than 30 percent over the entire period.

Energy consumption in Saudi Arabia accelerated after 1970 when the first Saudi Arabian development plan was launched. Such a rapidly increasing

TABLE XIX

NATURAL GAS PRODUCED, RE-INJECTED, FLARED AND SHRINKAGE
(MILLION CUBIC METERS)

Classification	1980	1981	1982	1983	1984
Produced					
Gross	53,265	52,382	33,564	26,900	29,050
Marketed	11,431	22,245	8,950	4,380	7,150
Flared	38,368	25,583	21,373	16,320	14,850
Re-Injected	270	1,411	1,651	1,300	1,250
Shrinkage	3,196	3,143	1,590	4,900	5,800

Source: Organization of Petroleum Exporting Countries. Annual Statistical Bulletin: 1984. Vienna, 1985

TABLE XX

ELECTRICITY GENERATING CAPACITY, PEAK LOAD, NO. OF SUBSCRIBERS AND QUANTITY PRODUCED, SOLD AND CONSUMED IN INDUSTRY IN ALL REGIONS

Year	Industrial Consumption Mega-W.	Energy Sold Mega-W./Hr.	Produced Energy Mega-W.	No. of Subscribers	Actual Peak Load Mega-W.	Generating Capacity Mega-W.
1975	2172673	3760009	4270146	351531	848	1173
1976	3023093	5322612	6388999	403275	1140	1780
% Increase	39.1	41.6	49.6	14.7	34.4	51.7
1977	3141576	6364620	7262996	465792	1633	2367
% Increase	3.9	19.6	13.7	15.5	43.2	33
1978	4564107	8465890	9713334	581806	2161	3210
% Increase	45.3	33.0	33.7	24.9	32.2	35.6
1979	6613133	13449403	15470086	726804	2955	4124
% Increase	44.9	58.9	59.3	24.9	36.7	28.5
1980	6840962	1743665	18908838	872054	3986	5904
% Increase	3.4	29.6	22.5	20	24.9	43.2
1981	7625619	21643686	25061449	1041958	5227	7359
% Increase	11.5	24.1	32.5	19.5	31.1	24.6
1982	10042756	26631129	31014329	1212314	6309	9145
% Increase	31.7	23.0	23.8	16.3	20.7	24.3
1983	8730652	*31176988	29915466	1390565	7796	10704
% Increase	13	17	3.6	14.7	23.5	18.9

*This includes the power provided by desalination plants.

Source: Central Department of Statistics. Statistical Yearbook: 1983. Ryadh, Saudi Arabia, 1983.

energy consumption during the last fifteen years was due to the following factors:

(1) The increase in income which is caused by the increase in oil revenues.

(2) Implementation of the three development plans which aim to increase economic growth and development programs.

(3) Changes in tastes and preferences of the Saudi Arabian people due to modernization, urbanization, education and high per capita income.

(4) Population growth. In 1960, Saudi Arabia's population was estimated by IMF to be 4.79 million as compared to 11.09 million in 1984. In addition to this and due to the labor scarcity problem that the Kingdom is facing, there have been more than two million foreign laborers working in Saudi Arabia during the last ten years.

As the Saudi Arabian rate of energy consumption increased during the last fifteen years, the structure of energy consumption also changed. This change in the structure of energy demand reflects the country's move away from its rural and traditional bases toward increased industrialization as well as urbanization. Assuming that the Saudi economy continues to move toward more industrialization as well as diversification and that the population continues to migrate to the modern Urban Centers, one may expect that commercial fuels will play an increasingly important role in the Kingdom's energy situation.

The use of commercial energy sources in Saudi Arabia has largely been confined to hydrocarbon products, mainly oil and gas. Although petroleum products have traditionally been the principal source of commercial energy in Saudi Arabia, the structure of energy consumption is undergoing change.

Plans are either already completed or scheduled for the near future that allow alternate energy sources to be utilized--gas, and hydroelectricity to mention only two.

Supply and Demand Balances

In recent years, Saudi Arabia as well as other nations have become increasingly concerned with the availability of energy resources to meet the increasing domestic energy demand. Energy situations indicate an increasing cost for energy resources used in the Kingdom. Four major options to reduce this high energy cost appear to be possible:

(1) Reduce energy consumption through market mechanisms and institutional constraints.

(2) Increase energy supply by introducing several energy resource alternatives.

(3) Increase efficiency in the use of energy resources through research and development programs.

(4) A combination of the three above.

In the short run, the first option appears to be applicable. In the long run, the other three options may introduce good results.

If we compare supply and demand patterns of petroleum refined products, it can be seen that supply and demand are unbalanced. While in some period there may be a surplus, in another there may be a shortage. The Saudi government has managed to balance the supply and demand by applying the following policies:

(1) Adjusting the refineries production according to domestic demand patterns.

(2) Expanding refining capacity to satisfy domestic demand.

(3) Using stock adjustment to narrow the gap between consumption and domestic refinery output over time.[9]

A hypothetical graph of supply and demand in Saudi Arabia is shown in Figure 2. At any given level of the official price, say P_0, the supply of petroleum refined products is perfectly elastic S_1, such that the quantity demanded is determined by the nature of the demand curve. If the price does not change but fuel consumption grows or declines such that the demand curve shifts out or shifts in to D_1 or D_2, the quantity consumed will expand to Q_1 or decline to Q_2.

Since price changes infrequently, this phenomenon generally occurs between price changes as the economy expands. If the official price is raised, say from P_0 to P_1, supply will still be perfectly elastic and, given D_1 and D_2, quantities will decline from Q_1 to Q_3 and from Q_2 to Q_4, respectively.

To encounter the supply and demand imbalances, the management of Saudi Arabia's petroleum refined products energy resources may take a two part problem. The first part consists of ensuring that an adequate supply of crude oil and related products are available for industrial and household usage. The second part consists of managing domestic demand effectively so that what is available is effectively used.

Energy Prices and Regulation

In Saudi Arabia energy prices are controlled by the government. Oil refined products are sold at fixed prices to gas stations who sell them at another fixed price. The government makes the decision when it is necessary

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[9]A. Al-Janabi, "Estimating Energy Demand in OPEC Countries," Energy Economics, Vol. 1, No. 2, (April 1979), p. 87.

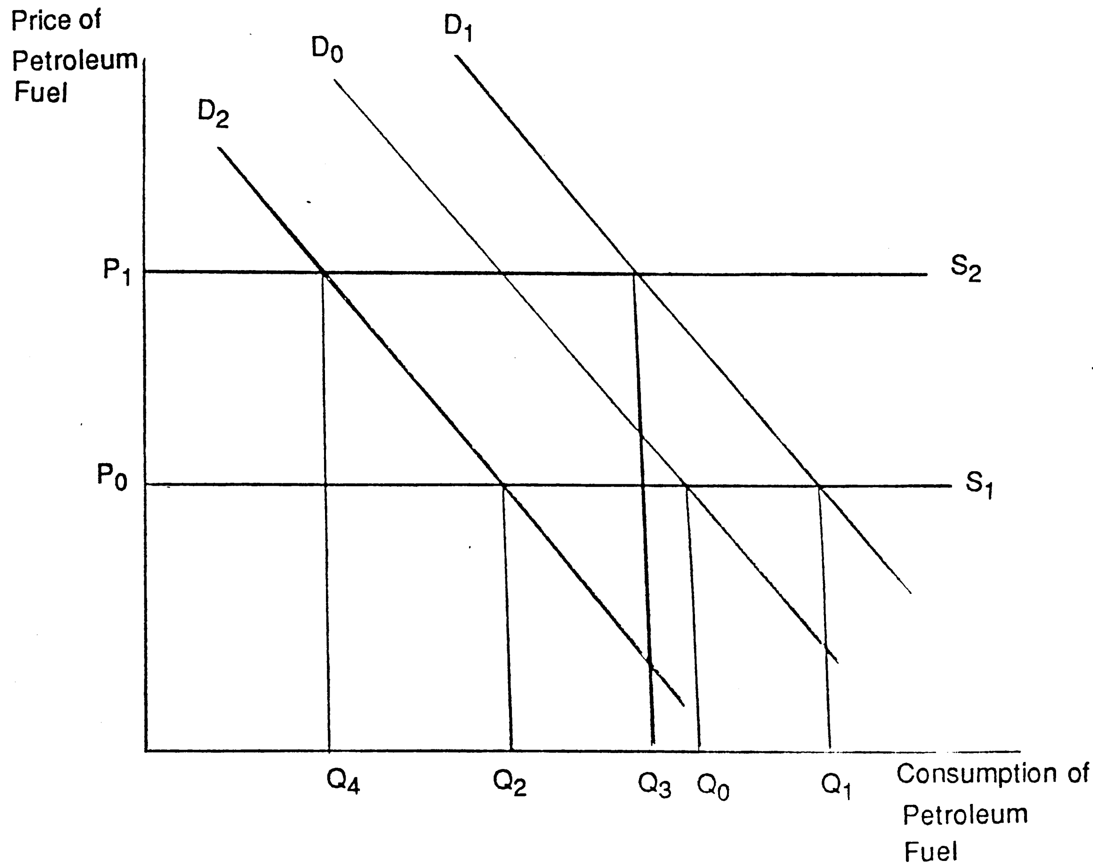

Figure 2. Supply and Demand of Petroleum Refined Products in Saudi Arabia

to change prices. Any increase or decrease in energy prices must be approved by the Saudi cabinet. Petromin, which markets and distributes the oil products, has no profit maximizing motive from domestic operations and its operations comply with the overall government policy rather than profit gains. Petromin is under close control by the government; the board director is the oil minister. Petromin is obliged to seek government approval for any proposed projects before starting construction.

Table XXI presents the wholesale prices of three refined products which were set by the Saudi government for the period 1967-1984. These prices were charged by Petromin to gas stations and others.

As the table shows, wholesale prices of petroleum refined products during this period were generally stable, despite the tremendous changes in the prices of oil products in the world markets. The only remarkable change occurred in 1984 when the supply prices were raised sharply. While the supply price of kerosene was almost double, the supply price of diesel was raised almost three times. The supply price of gasoline was raised by 75 percent.

Table XXII presents the retail prices of the three refined products for the period 1967-1984. Again these prices are set and controlled by the government. These are the prices that were charged by gas stations and others. For some periods these prices include taxes. In the 1960's the Saudi government charged 5 percent sales tax on all petroleum products sold domestically. However, in the early 1970's, taxes were canceled. Again the big jump is in 1984 when retail prices were raised sharply. While the retail price of gasoline was raised by 62 percent, the price of diesel was raised by almost 72 percent and the retail price of kerosene was raised by 47 percent.

TABLE XXI

WHOLESALE PRICE OF PETROLEUM REFINED PRODUCTS IN NOMINAL TERM (SR/GALLON)*

Year	Gasoline	Kerosene	Diesel
1967	.67	.30	.26
1968	.67	.30	.26
1969	.67	.30	.26
1970	.80	.30	.36
1971	.83	.30	.31
1972	.70	.30	.26
1973	.70	.30	.26
1974	.47	.29	.14
1975	.33	.27	.12
1976	.33	.27	.12
1977	.33	.27	.12
1978	.44	.31	.13
1979	.54	.34	.13
1980	.54	.34	.13
1981	.54	.34	.13
1982	.54	.34	.13
1983	.54	.34	.13
1984	.93	.67	.45

Source: General Organization of Petroleum and Mineral (Petromin). Personal Contact.

*SR = Saudi Riyal, 3.75 = one U.S. dollar

TABLE XXII

AVERAGE RETAIL PRICE OF PETROLEUM IN REFINED PRODUCTS IN NOMINAL TERM
(SR/GALLON)

Year	Gasoline	Kerosene	Diesel
1967	.75	.40	.35
1968	.75	.40	.35
1969	.73	.40	.35
1970	.88	.40	.40
1971	.90	.50	.43
1972	.90	.50	.43
1973	.90	.56	.43
1974	.63	.42	.28
1975	.63	.42	.28
1976	.63	.42	.28
1977	.63	.42	.28
1978	.71	.51	.26
1979	.71	.51	.26
1980	.71	.51	.26
1981	.71	.51	.26
1982	.71	.51	.26
1983	.71	.51	.26
1984	1.14	.76	.45

Source: Ministry of Commerce, personal contact and Statistical Yearbook of Saudi Arabia. Various issues.

In 1984, the big jump in oil product prices may be due to several factors:

(1) The decline in oil export revenue which caused financial shortages and consequently a budget deficit.

(2) Implementation of consumption conservation program in different situations in the Kingdom.

The rest of the energy sources that have been consumed in the Kingdom are natural gas and electricity. Table XXIII presents their consumer prices for the period 1966-1984. As is shown, they are more stable than oil products, despite the tremendous changes in the Kingdom's economic activities and the high inflation rate for some periods.

Petroleum product prices in Saudi Arabia are established by the central government and administered through Petromin and the Ministry of Commerce. These prices could be viewed as an instrument of public policy and reflect the aims of the government rather than the equilibrating mechanisms of the marketplace. Changes in prices have come infrequently. As shown in Table XXI and XXII, domestic fuel prices have changed only a few times during the last 18 year period.

The prices displayed in Table XXII are the retail prices paid by the consumers. Table XXI displays the wholesale prices paid by the gas stations and other buyers. It can be seen that change in the patterns of wholesale prices during the last 18 year period are similar to those in retail prices. The divergence between wholesale and retail prices reflects the wholesaler's cost and profit. Wholesaler cost includes operating cost, transportation cost, and, in some years, taxes.

The OPEC price increase of 1973-74 and 1979 was not a reason to increase domestic oil prices. During this period, fuel oil prices were decreased

TABLE XXIII

AVERAGE ELECTRICITY AND NATURAL GAS PRICES
IN SAUDI ARABIA IN NOMINAL TERM
(SR/25 LB)

Year	SR/K.W.H.	SR/25 LB
1966	.20	3.25
1967	.19	3.25
1968	.19	3.25
1969	.19	3.25
1970	.19	3.25
1971	.19	3.25
1972	.19	3.20
1973	.19	3.25
1974	.07	3.25
1975	.07	3.25
1976	.07	4.25
1977	.07	4.25
1978	.07	4.25
1979	.07	4.25
1980	.07	4.25
1981	.07	5.00
1982	.07	5.00
1983	.07	5.00
1984	.07	7.50

Sources:
For Electricity Price: Ministry of Industry and Electricity, Personal Contact.
For Natural Gas: Ministry of Commerce, Personal Contact.

several times. This was a wrong policy since it had different negative economic consequences. The absence of market forces led to the loss of some benefits.

It should be mentioned that in Saudi Arabia those who are responsible for setting fuel prices, an ad-hoc committee of representatives from several government agencies, are not exactly those responsible for the wholesale of the fuel in question. The retailer does not have any influence in fuel price setting. Prices are established with regard to economic and/or social and political objectives in mind: the least of these may be the profit maximization incentive.

CHAPTER IV

AN ECONOMETRIC MODEL FOR THE DEMAND OF PETROLEUM REFINED PRODUCTS IN SAUDI ARABIA

Introduction

The model to be specified herein will describe and analyze the demand for petroleum refined products in Saudi Arabia. It will reflect an equation for each petroleum refined product to be estimated. The major refined products which will be estimated and analyzed are the following: gasoline, kerosene, and diesel. The demand equations which have been specified herein are rested both in the economic theory and the institutional framework of Saudi Arabia. Those equations are specified in log and dynamic flow adjustment forms for gasoline and diesel so that the effects of the explanatory variables are spread over time and in static form for kerosene.

Energy demand is either direct or indirect demand. The determinants of energy demand could be either economic or technological. Among the economic determinants are: price of energy product, money income, price of related goods, tastes and preferences of the individual, population size, degree of industrialization and cultural factors. Among the technological determinants is the efficiency of energy resources utilization. The demand for energy resources, on the other hand, arises from the various uses to which it can be put to satisfy various wants. Some of these uses can be identified as: commercial, industrial, agricultural, residential, transportation and utilities.

Specification of the Model

It has been mentioned earlier that the most relevant factors which determine the demand for a product are income and price. Following the theory of consumer behavior and previously cited literature, an econometric technique will be used to estimate and project the demand for the petroleum refined products in a capital surplus - labor shortage economy with many structural changes since 1970.

In the simplest formulation, the demand for crude oil can be seen as the demand for oil refined products since oil is put to different uses only after it has been refined. This could be represented in the following equation:

$$\sum_{t=1}^{3} X_{it} = D_t \qquad (1)$$

where:

X_{it} = the per capita demand for the refined product i at time t in United States barrels.

D_t = the total crude oil used in producing the three products in United States barrels at year t.

In general, the desired demand for each refined product will be specified in the following functional form:

$$X_{it} = f\,(P_{it}, Y_t) \qquad (2)$$

where:

P_{it} = the price of product i at time t deflated by the CPI (1980 = 100) and in Saudi Arabian Riyals.

Y_t = real per capita income at time t in Saudi Arabian Riyal (1980 = 100).

For simplicity, equation (2) can be written with the error term included for estimation purposes as follow:

$$X_{it} = \alpha_0 + \alpha_1 P_{it} + \alpha_2 Y_t + e_t. \qquad (3)$$

Equation (3) is the main general equation used in different energy estimation and projection.

The Gasoline Equation

Using equation (3), gasoline is estimated using the following log linear form of equation (3):

$$\log X_t = \alpha_0 + \alpha_1 \log P_t + \alpha_2 \log Y_t + e_t. \qquad (4)$$

However, the actual demand for gasoline is not necessarily equal to the desired level. Therefore, actual demand will adjust with the desired demand. In this case, the change in the desired demand is related to the difference between the demand in period t and the actual demand in period t-1. So the adjustment process would be:

$$\Delta \log X_t = \Gamma (\log X_t - \log X_{t-1}) \qquad (5)$$

where:

Γ = the adjustment coefficient, $0 < \Gamma < 1$.

Δ = the change in demand = $\log X_t - \log X_{t-1}$.

Substituting (4) into (5), we obtain the logarithmic dynamic partial adjustment demand equation form as follows:

$$\log X_t = \Gamma\alpha_0 + \Gamma\alpha_1 \log P_t + \Gamma\alpha_2 \log Y_t + (1-\Gamma) \log X_{t-1} + \Gamma e_t. \qquad (6)$$

In a more convenient form, equation (6) could be written as follows:

$$\log X_t = B_0 + B_1 \log P_t + B_2 \log Y_t + B_3 \log X_{t-1} + e_t \qquad (7)$$

where:

X_{t-1} = last year per capita consumption of gasoline in United State barrels.

$P_t =$ price of gasoline, Saudi Riyal per barrel at time t in real term (1980 = 100).

$Y_t =$ per capita income in Saudi Riyals at time t in real term (1980 = 100).

$X_t =$ per capita gasoline consumption in United States barrels at time t.

$B_0 = \Gamma\alpha_0$.

$B_1 = \Gamma\alpha_1$.

$B_2 = \Gamma\alpha_2$.

$B_3 = (1-\Gamma)$.

$e_t = \Gamma e_t$.

B_0, B_1, B_2, and B_3 parameters to be estimated.

The sign of these parameters are expected to be as follows:

$\frac{\partial X}{\partial P} < 0$, that is the price elasticity of gasoline, $B_1 < 0$.

$\frac{\partial X}{\partial Y} > 0$, that is the income elasticity of gasoline, $B_2 > 0$.

$\frac{\partial X}{\partial X_{t-1}} > 0$, that is the last period impact, $B_3 > 0$.

The Diesel Equation

Again, using equation (3), diesel is estimated in the same manner as the gasoline case but income is not used. The log linear form for diesel is as follows:

$$\log X_t = \alpha_0 + \alpha_1 \log P_t + e_t. \quad (8)$$

Using the flow adjustment process, similar to the gasoline case, we end up with the following equation for diesel:

$$\log X_t = B_0 + B_1 \log P_t + B_2 \log X_{t-1} + e_t \quad (9)$$

where:

$X_t =$ per capita consumption of diesel in United States barrels at time t.

P_t = price of diesel, Saudi Riyals per barrel at time t in real term (1980 = 100).

X_{t-1} = last year's per capita consumption of diesel in United State barrels.

B_0, B_1, and B_2 are parameters to be estimated.

The sign of the parameters are expected to be as follows:

$\frac{\partial X}{\partial P} < 0$, that is the price elasticity of diesel, $B_1 < 0$.

$\frac{\partial X}{\partial X_{t-1}} > 0$, that is the last period impact, $B_2 > 0$.

The Kerosene Equation

Equation (3) is used to estimate kerosene consumption in a static form framework and using a linear function similar to equation (3) as follows:

$$X_t = \alpha_0 + \alpha_1 P_t + \alpha_2 Y_t + e_t. \qquad (10)$$

In this case, since kerosene could be substituted by natural gas, the price of natural gas is added to equation (10) in order to capture the effect of substitution. Equation (10) could be written then as follows:

$$X_t = \alpha_0 + \alpha_1 P_t + \alpha_2 Y_t + \alpha_3 P_j + e_t \qquad (11)$$

where:

X_t = per capita kerosene consumption at time t in United States barrels.

P_t = the price of kerosene, Saudi Riyals per barrel at time t in real term (1980 = 100).

Y_t = per capita income in Saudi Riyal at time t in real term (1980 = 100).

P_j = price of natural gas, Saudi Riyal per 25 bound at time t in real term (1980 = 100).

α_0, α_1, α_2, and α_3 are parameters to be estimated.

The sign of the parameters are expected to be as follows:

$\frac{\partial X_t}{\partial P_t} < 0$, that is $\alpha_1 < 0$.

$\frac{\partial X_t}{\partial Y_t} > 0$, that is $\alpha_2 > 0$.

$\frac{\partial X_t}{\partial P_j} > 0$, that is $\alpha_2 > 0$ if j is substitutable to kerosene.

In the above formulation, we have to mention that we assume, as several others did, zero cross partial effects between the three petroleum refined products in question. That is, the consumption of one product will not affect the consumption of the others. In addition, most of the previous studies of petroleum refined products demand ignored the supply side of the market; the current study follows in that tradition due to some difficulties in obtaining complete supply side data set on one hand and the unlimited supply of crude oil in Saudi Arabia on the other hand.

Some Econometric Issues

Causality

In estimating the reduced form equation for the three refined products, one way causality is implicitly assumed between the level of consumption of those products and the selected independent variables. In Saudi Arabia the fuel oil supply is perfectly elastic. This implies that prices and supply are independent of each other and one way causality exists. In this case, the direction of causality is from prices to demand. However, actual and precise conditions in the Kingdom are less clear in this regard.

The prices of petroleum fuels in the Kingdom are established on a nation-wide basis by the central government and are infrequently altered. Petromin, which has the sole responsibility for petroleum products distribution, is obligated to meet all domestic demand at the established price. In the short-run, fuel prices are independent of the amount consumed. Low administered prices related to high demand level became, in recent years, a negotiable issue between government officials and economists. Internal and external pressures to increase domestic prices in order to increase government revenues to ease the Kingdom budgetary problems are taking place.

Overall, there does exist an indirect flow of causation from petroleum fuel demand to fuel prices, but this requires several years to be felt in a slight manner.

Estimation

This concept refers to the issues involved in applying some unique statistical techniques to the market data to perform some statistical properties. Income data that could be used are either GNP, GDP, GNP per capita, disposable income, or national income. Price may be in nominal or real terms. Observations could come from either National Income Account or Cross-section data. Measurement errors are possible and may be reported by official agencies in many developing countries. It seems that more knowledge about the data being used is important in order to correct or adjust for obvious error wherever possible. Moreover, the use of time series data allows one to obtain a good response of the independent variables in relation to the dependent variable.

The petroleum fuels model presented herein consists of an independent single equation estimated for each of the three petroleum products mentioned earlier. A multiple regression analysis, using OLS, was the main principal statistical tool used to estimate the three equations. This approach is used to estimate two equations in log linear dynamic demand form and the third equation in a static form. As many pointed out, this approach is the most commonly accepted in modeling energy demand behavior.[1]

Testing Hypothesis

In this concept, statistical test and criteria were used to judge whether the three demand equations were valid and could be used as a reliable predictor. The estimated parameters could be tested to determine whether they are statistically reliable and could be used. The coefficient of determination could be used to determine the strength of the relationship between the independent and the dependent variables. The adjusted coefficient of determination is the main measure of the explanatory power of the regression equations. The t-statistics and F-statistics are the criteria for accepting or rejecting the null hypothesis.

Rao and Miller (1971) sum up the practical application of statistical test in regression as follows:

> The use of these statistics is especially valuable in applied econometrics where their role is not always to provide cut-and-dried answers. Instead they are the basic tools of the applied econometrician in working his way through an empirical problem. The typical "textbook" econometric problem in which the model is clearly specified is seldom encountered in empirical research. Applied econometricians use a great deal of judgement at various stages of research by utilizing summary statistics to 'feel the data' (p. 13).

The combination of the F-statistics test and the adjusted R^2 will enable a researcher to have some confidence in the explanatory power of variables in a

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[1]See for example: D.R. Bohi, Analyzing Demand Behavior, (Baltimore, Johns Hopkins University Press, 1981), pp. 14-33.

given equation. The Durbin-Watson and Durbin-h were used as the criteria to detect serial correlation in the estimated equation.

Multicolinearity

Multicolinearity refers to the situation in which two or more explanatory variables in the regression equation are highly correlated, making it difficult to isolate their individual effects on the dependent variable.[2] In this case, the estimated coefficients may become statistically insignificant and may have a high R^2. As Johnston noted, high colinearity among regressors is known to reduce the precision of the estimates, lead to specification errors and make the estimate sensitive to another data set.[3] If multicolinearity existed, it could be overcome or reduced by several procedures:[4]

(1) change the data set.

(2) drop the variable that causes multicolinearity.

(3) do nothing and do the analysis.

(4) transform the functional form.

(5) use principle component.

(6) use an estimate of coefficient done somewhere else.

(7) convert data to first differences.

(8) combine two variables into one by forming a ratio.

(9) use extraneous information.

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[2]D. Salvatore, Statistics and Econometrics, (New York, McGraw-Hill Book Co., 1982), p. 182.

[3]J.J. Johnston, Econometric Methods. (New York, McGraw-Hill Book Co., 1972), p. 100.

[4]P. Kennedy, A Guide to Econometrics, (Cambridge, Mass., 1981), p. 131, and Ag. Econ. Econometrics Class Notes.

(10) use cross section data to estimate some parameters.

(11) increase sample size.

With multicolinearity, a data problem exists. However, the use of per capita consumption and per capita income as used by Kennedy (1974), Pagoulatos (1975), Pindyck (1979), and Kainain (1983) will minimize the multicolinearity problem in the estimation process. This idea was followed in this dissertation by using real per capita income and per capita consumption of each product in question. In some situations where a very high correlation existed between some of the independent variables, one of them is dropped. This is the case where the number of registered cars were dropped due to the high correlation between it and the income. In another situation, the consumption of kerosene as reported in a Saudi publication was substituted by consumption data from the United Nations publications. More on these will be presented in the next chapter.

In Saudi Arabia, real prices of energy products have been falling while income has been rising. Table XXIV shows the real prices of energy products together with real per capita income during the observation period. Per capita income was calculated using actual GNP expenditures taken from statistical yearbooks. The low energy product prices and the high per capita income affect the consumption of energy products positively and will introduce some ambiguity in data interpretation. It is possible that confusion will arise in the upward trend in energy products consumption. It is really difficult to decide if the rise of energy consumption is due to high income or a low energy price. A high standard error of price and income may exist. To minimize this, a time series data should be used in the estimation process.

TABLE XXIV

PETROLEUM PRODUCTS PRICES, NATURAL GAS PRICE, AND PER CAPITA INCOME IN REAL TERM FOR THE PERIOD 1967-1983 (ALL IN SAUDI RIYALS)

Year	Real Price of Gasoline	Real Price of Diesel	Real Price of Kerosene	Real Price of Natural Gas	Real Per Capita Income
1967	105.000	49.0000	56.0000	10.8333	2887.1
1968	103.279	48.1967	55.0820	10.6557	3096.8
1969	97.025	46.5190	53.1646	10.2848	3131.0
1970	116.962	53.1646	53.1646	10.2848	3256.4
1971	114.182	54.8485	63.6364	9.8485	5121.1
1972	109.217	52.4638	60.8696	9.4203	5823.6
1973	93.731	45.0249	58.4577	8.0846	8393.7
1974	54.078	24.3852	36.2705	6.6598	13448.4
1975	30.544	13.7731	20.4861	4.9190	17709.9
1976	40.229	18.1402	26.9817	6.4787	26265.9
1977	30.544	13.7731	20.4861	4.9190	19398.9
1978	30.988	11.5385	22.3493	4.4179	17846.6
1979	31.478	11.7212	22.7033	5.2798	22247.1
1980	29.810	11.1000	21.5000	5.0000	26543.9
1981	29.026	10.8082	20.9348	4.8685	30131.4
1982	28.7187	10.6936	20.7129	4.8169	30192.7
1983	28.4447	10.5916	20.5153	4.7709	23809.2

Notes:

(1) Compiled from tables XXII, XXIII and from statistical yearbooks actual expenditures.

(2) To find per capita income we use population figures from international financial statistics.

(3) To find real prices and income we deflated by CPI from United Nations Monthly bulletin of Statistics.

Measurement Error

In this respect, measurement error may occur due to differences in the measurement unit used. One may use the barrel unit of measurement for some variable or the gallon unit measurement. Measurement error may occur between different estimations and also within one estimation if units of measurement are different. The estimated coefficient and R^2 may be the same from two different estimations that used different measurement units but the intercept may be different. In our study we tried to minimize the error created by using different measurement units. The barrel unit measurement in consumption is being used. Also, the same currency term, that is the Saudi Riyal, is being used.

Another problem we have encountered in this dissertation is the fact that the income variable is not included in the diesel case. In economic theory, demand for a product is a function of its own price, income, and other things. Although several studies included this variable in diesel demand estimation, statistical estimation for Saudi Arabia showed that this variable does not perform very well. Empirical results show that there is no relationship between diesel demand and income in Saudi Arabia. Pindyck estimated energy demand in developing countries with the exclusion of price. As he mentioned earlier, the price role in developing countries is not clear.[5]

The final statistical problem encountered in this dissertation is due to the presence of the lagged dependent variable as independent variable in gasoline and diesel equation. This creates a possible existence of autocorrelation in the error term which may lead to a biased estimate of the

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[5]R. S. Pindyck, "Energy Demand In Developing Countries," in Pindyck, R. S. The Structure of World Energy Demand, Cambridge, Mass., The MIT Press, (1979), pp. 248-265.

parameters. A further test to detect this problem is calculated. The Durbin-h test, as shown in the next chapter, proves that there is no autocorrelation problem at all in the equation in question.[6]

Specification of the Dependent Variable

The dependent variable used in each estimated equation represents the estimated demand for each fuel. Petroleum fuels sold in the Kingdom domestic market are believed to be a reasonable estimator of actual demand. Domestic sales are the domestic consumption that are purchased and sold at the controlled prices within the Kingdom boundary. As we mentioned earlier, the sales quantities used in this study were taken from the Petroleum Statistical Bulletin prepared by the economic department of the Ministry of Petroleum and Mineral Resources. Since Petromin is the sole distributor of petroleum products in the Kingdom and is controlled and administered by the Ministry of Petroleum and Mineral Resources, these statistics represent the actual total domestic demand of those fuels in Saudi Arabia.

Specification of the Independent Variables

The variables that are examined in this case as independent variables are as follows:

(1) price of the fuels in question.

(2) consumer income.

(3) the previous year fuels consumption.

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[6]For detail see: J. Durbin, and G.S. Watson, "Testing for Serial Correlation in Least Square Regression," Biometrica, Vol. 38, 1951, pp. 159-178.

(4) the price of substitute in the kerosene case.

The petroleum products studied in this dissertation were distributed entirely by Petromin and sold at the official government prices. During the observation period, the cost of living index in the Kingdom has been fluctuating. While it was 4.9 percent in 1970, it was 34.6 in 1974 and 5 percent in 1979. Inflation follows the same path. In 1970, inflation was 11.1 percent and in 1974 it was 42.3 percent. In 1979, inflation had been reduced to only 3.0 percent. The rate of official price increases for the three products lagged behind the cost of living and inflation during the observation period.

Consumer income used in the estimation process of this study is the actual income expenditures per capita. It was adjusted by the CPI to reflect the constant purchasing power. According to the wide literature on the relationship between income and energy consumption, this variable is important in explaining the relationship between dependent and independent variables. The annual data of this variable were divided by population and consumer price index to derive an estimate of the actual real per capita GNP expenditures. It was hoped that actual expenditures per capita would serve as a meaningful indicator of consumer income since most of the fuels in question are consumed directly or indirectly by a large segment of the population.

In the model, consumer habit was represented through the use of the partial adjustment specification which treated the dependent variable lagged one period as an independent variable. The inclusion of this variable converted the demand equations from static framework to a dynamic adjustment one. The rationale behind the inclusion of the lag dependent variable can be justified as follows: In Saudi Arabia, energy consumption in a specific year is related to what has been consumed and accomplished in the previous year, since most of it is directly linked to the infrastructural projects, sectoral development and social overhead changes.

Of the fuels studied, kerosene is the only product that has a substitute in Saudi Arabia. Kerosene can be substituted by either natural gas or electricity. However, due to the unavailability of electricity in every place during the entire observation period and due to the structural changes in most of the period, only the natural gas price is included in our estimation. During the entire period, not everyone who wanted to buy kerosene or electricity at their specified price could obtain them as compared to the natural gas case.

The number of registered vehicles that should be incorporated into the demand equation for gasoline was deleted due to high correlation between it and income.

Limitation of the Model

The model formulated in this chapter has some limitations and weaknesses when it is applied to the Saudi Arabian energy market. The first limitation concerns the sample size used in estimating the model. A sample size of seventeen observations is not econometrically enough to perform an accurate and efficient forecasting and estimation. Econometric results of forecasting may not be as reliable with this model compared to a larger size observation estimated in other countries. The second limitation concerns data accuracy. Most of the data in less developed countries are not accurate and not classified well enough to obtain good statistical results. Aggregation is a clear problem in this case. The final limitation concerns applicability range of the model. While some variables play an important role in determining demand for one product, it is not applicable at all with another in less developed countries.

CHAPTER V

ANALYSIS OF THE EMPIRICAL RESULTS

Introduction

This chapter contains the estimated results and analysis of the demand for gasoline, kerosene and diesel. All of the estimates were conducted using annual data for each variable with ordinary least square techniques. This estimate was compared with economic theory and market conditions.

The demand for the three petroleum products was estimated with alternative models in order to determine the best representative estimates. In the estimation of both the dynamic and the static models, the following variables were included in several attempts:

(1) In the gasoline equation, the number of registered cars was included, together with price and income. Dynamic and static models were estimated but did not give good statistical results. A different definition of income levels was included in the estimated equation. However, statistical results were still poor.

(2) In the diesel case, several variables in addition to price and income were included in the equation. Those variables are: growth rate, time trend, growth rates of industrial activity, the number of registered cars, different definition of income levels, manufacturing growth rates, aggregate investment, investment in machinery, and investment in manufacturing. Several attempts with different combinations of these variables using both

dynamic and static framework were performed but no good results were obtained.

(3) In the kerosene equation, the price of electricity and a different definition of income level were included in the estimation process, using both dynamic and static framework. The statistical results were not qualified to be reported.

It should be mentioned that several estimation attempts using different combinations of the available variables have been performed, but their statistical results were not satisfactory enough to be reported in this dissertation. The estimated results presented in this chapter are the best ones that were achieved among the estimation attempts.

Attention in this chapter focuses on the estimation of price and income elasticity as well as the impact of substitutable products and the previous year's consumption. By estimating these coefficients, a more accurate prediction of future demand of petroleum refined products in question can be achieved and analyzed.

In the following sections, the demand for the petroleum refined products in question was estimated, using a dynamic demand equation for gasoline and diesel while a static equation is used for kerosene. The dynamic elements of the demand equation formulation are very important, since they may reflect the consumer habit. The quantity demanded at this period of time will affect the quantity demanded in the next period. These equations were fitted in time series data for the period 1967-1983. Relative real prices and real income were introduced as determinant factors in fuel oil demand. The static linear form was the best formulation that achieved the best results in the kerosene case.

Analysis of Gasoline Estimation

Gasoline represents the principal transportation fuel used in the Kingdom of Saudi Arabia. During the observation period of this study, 1967-1983, demand for gasoline in the Kingdom rose from 5 million barrels in 1970 to 48.1 million barrels in 1983. The relative share of gasoline consumption in the total petroleum consumption declined from 16.4 percent in 1970 to 13.4 percent in 1983.

In most of the observation period, two grades of gasoline - regular and premium - were offered, but only one is available in recent years. Both grades are used primarily by automobiles, small buses and motor cycles. However, available data shows an aggregate quantity for both grades of gasoline.

In Saudi Arabia, gasoline is distributed and marketed by Petromin. Petromin is the wholesale agent. Sales to large customers, especially to government agencies and state enterprises and big firms, are handled by Petromin while sales to road customers are principally handled by retail dealers, i.e., gas stations, who buy gasoline originally from Petromin. No time series data are available regarding the distribution of gasoline consumption by household characteristics or by each economic sector. Also, no official data for large customers are published in aggregate or disaggregate forms.

The transportation system in Saudi Arabia during the observation period was mainly characterized by the use of vehicles for people movement and travel. Railroad transport was available in certain areas and played a minor role in transportation. Airline transportation is growing as more airports in different parts of the Kingdom are built.

In Saudi Arabia, most of the available road surface is in good condition and highway system construction and improvement programs have been underway since 1977. Over time, the structure of road transportation underwent a number of significant changes. The length of the available roads has more than doubled. Table XXV shows the road improvement in terms of the number of miles constructed over the observation period. As is shown, the number of miles constructed in 1983 is eight times what was in existence in 1967. At the same time, the number of registered vehicles grew rapidly during the observation period. Table XXVI shows this growth. As is shown, the number of registered cars in 1983 is almost fifty times what it was in 1967. This of course trebled the number of vehicles per kilometer of the available road and increased the domestic consumption of gasoline from 3.2 million barrels to 48.1 million barrels in 1967 and 1983 respectively. However, an analysis of the correlation of the gasoline equation with the number of registered cars included, as shown in the correlation matrix Table XXVII, suggests that multicolinearity is the reason for the poor performance. As appears in Table XXVII, income and the number of registered cars are highly correlated. Therefore, the number of registered cars was thus dropped from the gasoline estimation.

We begin the analysis of the empirical works with the demand for gasoline. A partial adjustment model of gasoline demand was fitted to the annual data and double-log-linear function. This function yielded the best results; therefore, it will be discussed below. The model used in gasoline estimation is:

$$\text{Log } x_t = \beta_0 + \beta_1 \log p_t + \beta_2 \log y_t + \beta_3 \log x_{t-1} + e.$$

The variables are as defined before in the previous chapter. The dependent variable in this equation is the per capita domestic consumption of gasoline.

TABLE XXV

ROAD IMPROVEMENT IN SAUDI ARABIA
(CUMULATIVE KILOMETERS CONSTRUCTED)

Years	Cumulative Miles Constructed
1967	7,650
1968	8,805
1969	10,440
1970	11,508
1971	12,497
1972	13,577
1973	14,710
1974	16,430
1975	19,753
1976	24,313
1977	28,345
1978	34,148
1979	39,019
1980	44,424
1981	49,741
1982	55,236
1983	62,397

Central Department of Statistics. Statistical Yearbooks: 1968-1975 and 1983. Riyadh, Saudi Arabia: Ministry of Finance, 1968-75 and 1983.

Central Department of Statistics. Statistical Indicators: 1977, 1978, 1982. Riyadh, Saudi Arabia: Ministry of Finance, 1977, 1978, and 1982..

TABLE XXVI

NUMBER OF REGISTERED CARS IN SAUDI ARABIA

Year	Number of Registered Cars
1967	12,621
1968	16,098
1969	22,789
1970	22,922
1971	22,805
1972	35,417
1973	62,789
1974	112,048
1975	159,339
1976	260,082
1977	338,530
1978	319,936
1979	290,207
1980	346,363
1981	398,424
1982	550,908
1983	523,906

Central Department of Statistics. Statistical Yearbooks: 1968-1975 and 1983. Riyadh, Saudi Arabia: Ministry of Finance, 1968-75 and 1983.

Central Department of Statistics. Statistical Indicators: 1977, 1978, 1982. Riyadh, Saudi Arabia: Ministry of Finance, 1977, 1978, and 1982..

TABLE XXVII

CORRELATION MATRIX OF GASOLINE EQUATION

Variable	Gasoline Consumption	Gasoline Price	Consumer Income	Registered Cars	Lagged Dependent Variable
Gasoline Consumption	1.00	-0.80	0.88	0.92	0.99
Gasoline Price	-0.80	1.00	-0.92	-0.91	-0.76
Consumer Income	0.88	-0.92	1.00	0.94	0.85
Registered Cars	0.92	-0.91	0.94	1.00	0.90
Lagged Dependent Variable	0.99	-0.76	0.85	0.90	1.00

This represents the total domestic gasoline sales. Its trend over time is shown in Table XVIII and Figure 3.

Gasoline is consumed by individuals as a transportation fuel. Actual GNP per capita serves as a measure of consumer income in the demand equation. This was included in the above equation as a per capita income in order to obtain more efficient results and to avoid some statistical problems.

The prices of gasoline used in the above equation are the official government prices adjusted for constant purchasing power using the general consumer price index for Saudi Arabia. The use of CPI reflect the idea that gasoline is a consumer commodity.

The tendency for consumers to change their gasoline consumption levels due to structural or behavioral rigidities was operationalized through the use of partial adjustment specification in the above equation.

So, the above equation relates the consumption of gasoline per capita to its own real price, real per capita income, and the previous consumption of gasoline. It is assumed that economic agents adjust instantaneously when price and/or income change by varying their consumption of gasoline. The equation was fitted to annual time series data for the period 1967-1983 and estimated using ordinary least square procedures. This estimate can be presented as follows:

$$\underset{}{\text{Log } x_t} = \underset{(-.216)}{-.0921} - \underset{(-2.604)}{.1184 \log p_t} + \underset{(2.589)}{.07789 \log y_t} + \underset{(29.913)}{.8545 \log x_{t-1}}$$

Durbin-Watson D Statistics = 2.592.

R-Square = .9982.

Adjusted R-Square = .9978.

The Durbin-h statistics are calculated to be -1.34.

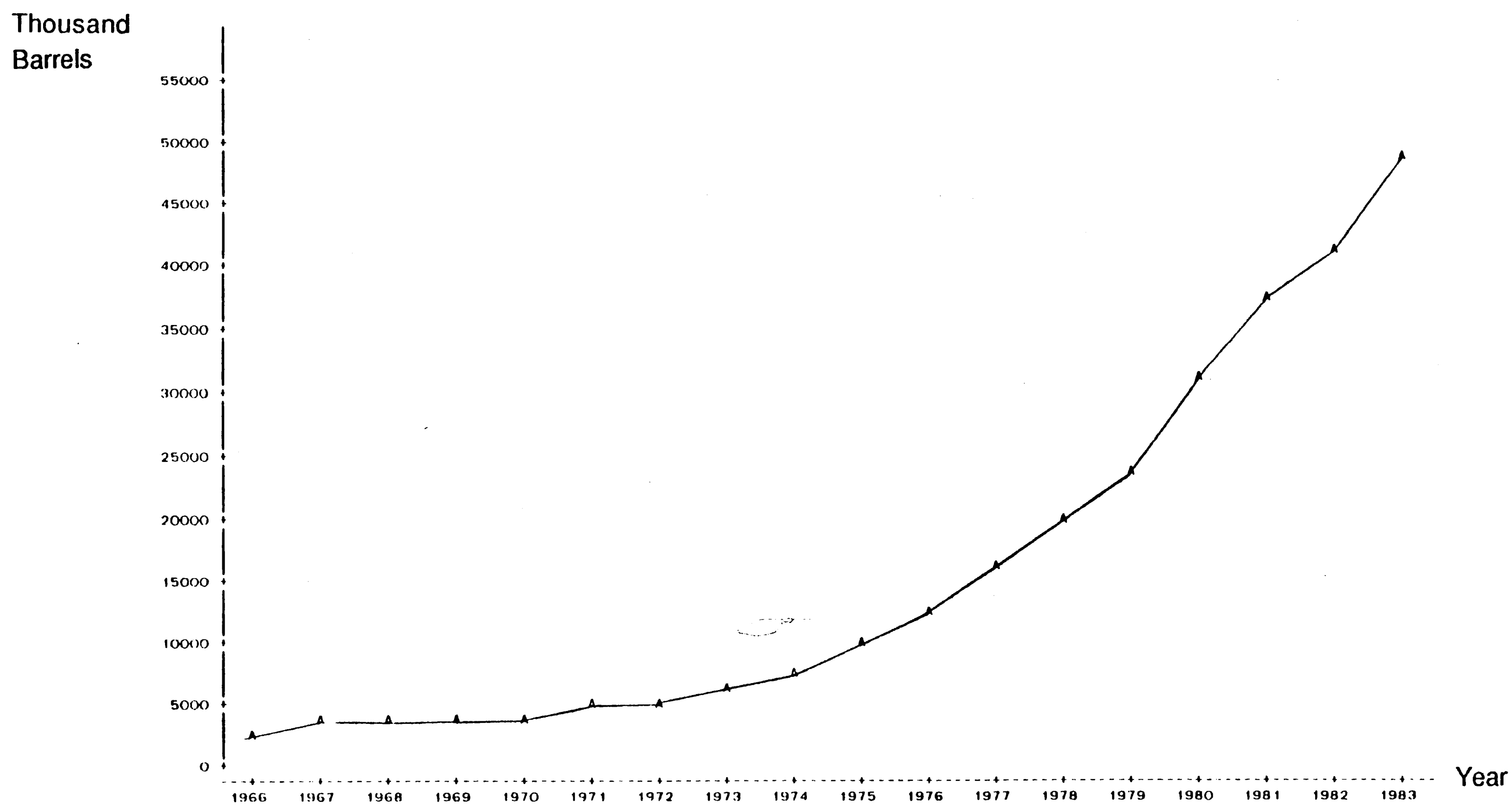

Figure 3. Gasoline Consumption Over Time

Given the above estimates for the gasoline equation, it is clear that all variables have the expected and correct signs and are significant at the .05 level. The values in the parenthesis are the t-test values for each variable in the equation. A value of 2.592 for Durbin-Watson D statistics and the existence of the lagged dependent variable in the right hand side require that a further check for the serial correlation problem is needed. This is done by calculating the Durbin-h statistics to detect autocorrelation. A value of -1.34 for Durbin-h statistics proves that serial correlation does not exist in the above equation. A high R^2 and $\bar{R}^2$ indicate that a good fit between the dependent and the independent variables existed.

Short-run elasticities for price and income are estimated to be -.11 and .07 respectively. These imply that gasoline demand is not price elastic in Saudi Arabia and that it is a normal good. Long-run price and income elasticities for gasoline are computed as follows:

$$\text{Long-run price elasticity} = \frac{\beta_1}{1-\beta_3} = -.81.$$

$$\text{Long-run income elasticity} = \frac{\beta_2}{1-\beta_3} = .53.$$

Again, long-run elasticities imply that gasoline in Saudi Arabia is inelastic and a normal good.

In evaluating gasoline equation results that used flow adjustment model specification, one may conclude that the model performed very well. All variables in this model have the correct signs and are significant at the .05 percentage level. Although the price of this product is controlled by the government, the statistical results obtained in this case proved the consumer theory assumptions with regard to the expected signs of all variables in question. In this respect, we may conclude that the demand for gasoline is characterized by the role of its price, consumer income and habit formation. It should be mentioned that the lagged demand variable absorbs most of the variation in the function, having a level of significant of .0001 and an estimated coefficient of .8545. This implies that the previous period consumption is a very important factor that determines demand in the current period. In this case, the equipment that used gasoline usually has a fairly long life. A car, for example, may remain active for 10 years or more.

Analysis of Diesel Estimation

Diesel fuel has the fastest growing rate of consumption in Saudi Arabia with an average growing rate of 32.2 percent in 1980. Its share represents the highest individual fuel consumed within the Kingdom boundaries. As is the case for the other fuels, Petromin has the distribution and marketing authority over diesel fuel. Retail sales of diesel fuel are comprised of roadside sales for motor vehicles as well as sales to various small enterprises and businesses. This is handled by retail dealers who own gas stations all over the country. Direct sales of diesel fuel are made by Petromin to several transportation facilities, such as certain automobile companies, the railroad, ships, and utilities and electricity generation companies. Other sales to different enterprises to operate diesel machines in different sectors of the economy are made. Very limited information concerning these sales is available.

From direct observation of the Saudi Arabian situation, one may figure out that during the observation period of this study several structural changes were made due to the rapid development of programs underway. The huge amount of investment in transportation and in machines and equipment are an indication that the number of trucks, automobiles and machines that used diesel fuel have been trebled. As we mentioned in Chapter III, several development programs were undertaken. Expansion of electricity generation capability, industrial development, the number of trucks, buses and machines used in the infrastructural and agricultural development are the main factors affecting diesel consumption in Saudi Arabia.

Let us now present the empirical results of the demand for diesel in Saudi Arabia. These results are based on the following dynamic flow adjustment equation:

$$\text{Log } x_t = \beta_0 + \beta_1 \log p_t + \beta_2 \log x_{t-1} + e_t.$$

The dependent variable of this equation consisted of the per capita domestic consumption of diesel fuel. In this case, it is difficult to determine precisely what share of diesel fuel consumption should be allocated to certain sectors of the economy.

The independent variables in the above equation consisted of diesel fuel price and a lagged dependent variable. The price of diesel fuel is defined as the official government price adjusted for constant purchasing power using the consumer price index to reflect the decision of modeling the demand for this fuel as a consumer good. The tendency for consumers to gradually change their fuel consumption levels due to behavioral or structural rigidities was operationalized through the use of the partial adjustment specification.

The above equation was estimated with a time series data for the period 1967-1983 by using ordinary least square procedures. The estimated results could be shown as follows:

$$\text{Log } x_t = \underset{(2.4)}{1.3105} - \underset{(-2.089)}{.3411} \log p_t + \underset{(7.348)}{.8089} \log x_{t-1}$$

R-Square = .9449.

Adjusted $\overline{R}$-Square = .9371.

Durbin-Watson D Statistics = 2.124.

The Durbin-h Statistics are calculated to be -.30.

As is shown, the price and the lagged variable coefficients have the expected signs and are also significant at .05 and .0001 levels of significance. The values in the parentheses are the t-test statistics for each variable in the equation, including the intercept. A value of 2.124 for the Durbin-Watson D statistics indicates that there is no serial correlation problem at all. But due to the existence of the lagged dependent variable, we calculated the Durbin-h statistics to detect if the autocorrelation problem existed or not. A value of -.30 for Durbin-h indicates that serial autocorrelation does not exist at all. A high R^2 and $\overline{R}^2$ values indicated a good fit in diesel equation. In the equation above, short-run price elasticity is estimated to be -.34, which implies a non-price elastic demand for diesel. Long-run price elasticity of diesel demand is calculated as follows:

$$\text{Long-run price elasticity of diesel demand} = \frac{\beta_1}{1-\beta_2} = -1.78.$$

This implies that diesel demand is elastic with respect to its own price. This is an unexpected result. The consumption of diesel has been increasing over the whole observation period and the price of diesel was fluctuating. Even if price increases, quantity is also increasing. It can be seen that the lagged dependent variable in the diesel equation absorbs most of the variation in the function, having a level of significance of .0001 and a coefficient of .8089. During the observation period, many development projects were undertaken. These projects require different equipment that use diesel. This equipment will stay active for a certain period of time and will affect diesel consumption in subsequent periods.

Analysis of Kerosene Estimation

The domestic consumption of kerosene fuel in Saudi Arabia used to represent a fairly substantial amount in the early 1960's, but gradually has a declining share of the total petroleum fuels. During the observation period, domestic kerosene consumption fluctuated. While it rises in some periods, the major trend is declining over most of the observation period.

Almost all of the kerosene sold in Saudi Arabia is marketed and distributed through independent dealers, i.e., gas stations, individuals or the like, who buy kerosene in large quantity from Petromin. The remainder is distributed by Petromin through their sales stations to airline companies and the armed forces. The airlines and the airforce consumption figures for kerosene are not included in the estimation.

In the early periods of our observation, kerosene was used for both cooking and lighting. It was used for cooking in urban households and for lighting in rural areas. In rural areas, kerosene competed with woodfuels and had no substitutes for lighting purposes. The efficiency of kerosene usage and ease of transport in rural areas insure its position to be an essential good relative to the other alternatives. In urban areas, on the other hand, kerosene is used for cooking more than lighting. In these areas, kerosene competes with a number of alternative fuels, two of which are natural gas and electricity. In recent years, urban households in Saudi Arabia have considerably greater access to electricity for lighting and heating purposes as well as greater access to natural gas for cooking purposes. In recent years the urban household, on the other hand, used electricity for cooking purposes, but this is very limited. As a result, the dependence of urban households on kerosene as the principle lighting and cooking fuel is less than in the rural household areas. This is due to greater availability of electricity and natural gas in urban areas as well as higher income, modernization and more transportation and service facilities. This implies that kerosene in urban areas is an inferior good. A disaggregation between the two regions is difficult since no detailed data and information are available.

The reduced form demand equation for kerosene, presented in Chapter IV, includes dependent and independent variables. The dependent variable for kerosene demand equation consisted of per capita domestic consumption. Annual domestic figures of kerosene sales are presented in Table XVIII in Chapter III and kerosene data used in this study are plotted over time in Figure 4. This graph illustrates the annual growth in kerosene sales in the Kingdom over the observation period. As is shown in Table XVIII and Figure 4, kerosene consumption has a decreasing growth trend over the entire observation period. The kerosene share of total refined product consumption has declined from 2.4 percent in 1967 to .38 percent in 1983.

The independent variables in the kerosene equation consisted of consumer income, kerosene price, and natural gas price.

The demand for kerosene was modeled as a consumer commodity demand equation. According to the consumer theory, consumer income plays a significant role in determining the household consumption of fuel. A strong positive relationship between the consumption of several goods and household income have been confirmed in different countries using different approaches. Therefore, it was anticipated that consumer income, represented by the real per capita income, would play a significant role in the kerosene demand estimation.

The price of kerosene in Saudi Arabia is regulated by the Ministry of Commerce and maintained at the official price levels, as is the case for other

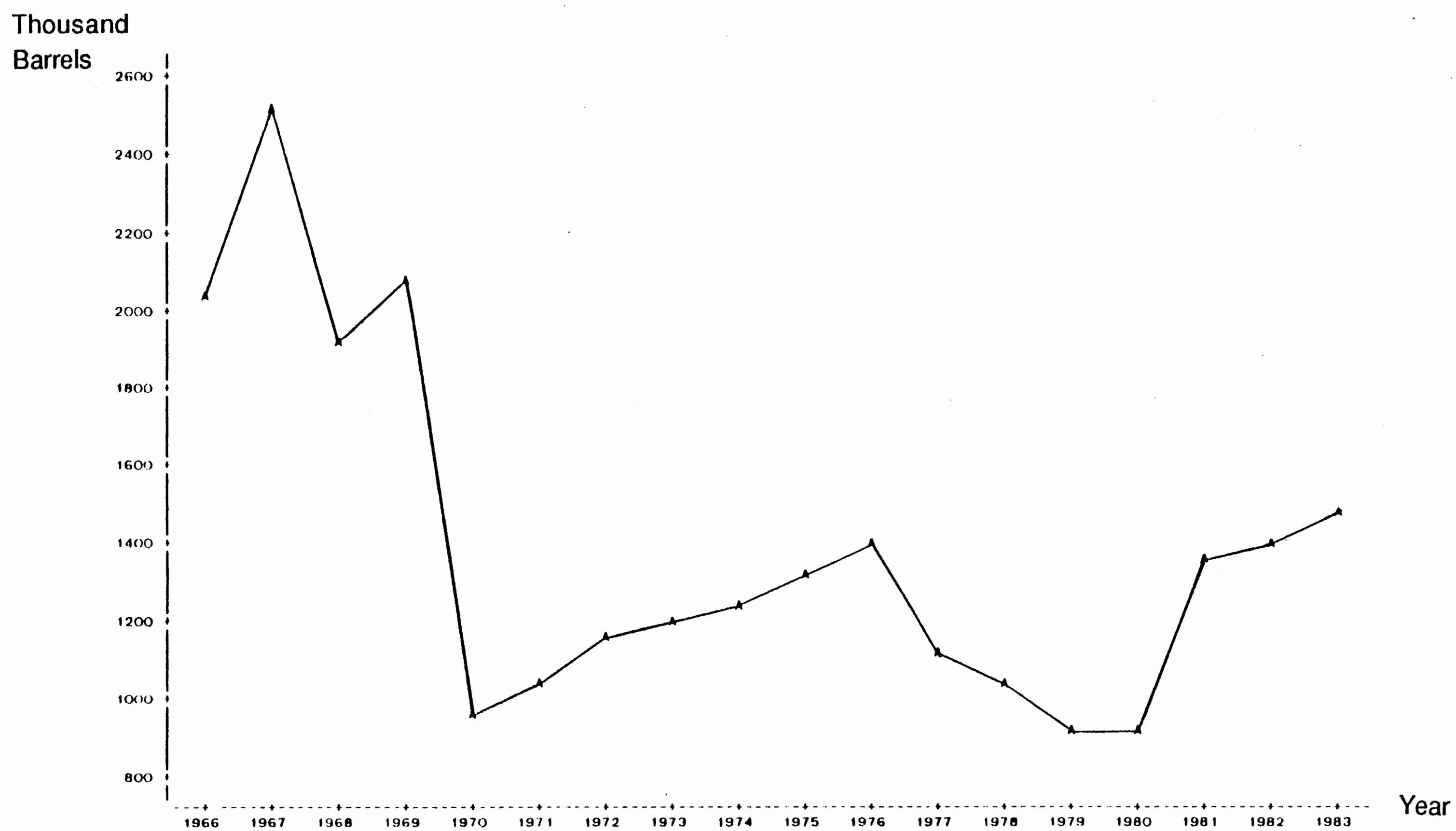

Figure 4. Kerosene Consumption Over Time

fuels. Petromin charges a standard wholesale price for kerosene at each depot scattered across the country. All or most of the transportation costs from refinery locations to the point of final consumption are absorbed or subsidized by the government. The official posted kerosene price used in the equation was adjusted for constant purchasing power using the general consumer price index for Saudi Arabia. The use of CPI reflects the idea of modeling the demand of kerosene as a consumer demand function.

Natural gas prices, the main substitute for kerosene in Saudi Arabia, were included in the equation and adjusted for constant purchasing power using the consumer price index also. Electricity is another substitute for kerosene, but due to the reasons mentioned in Chapter IV, it is not included in the equation.

Now the results of kerosene demand in Saudi Arabia will be reported. In obtaining the results, the following equation was used:

$$x_t = \alpha_0 + \alpha_1 p_t + \alpha_2 y_t + \alpha_3 P_{jt} + e_t.$$

As was done with gasoline and diesel, the above equation is estimated with ordinary least squares by using time series data for the period 1967-1983. As mentioned above, the per capita consumption of kerosene at time t is assumed to be a function of per capita real income, real kerosene price, and the real price of natural gas. The results obtained from the regression procedures are as follows:

$$\begin{array}{l} x_t = .0345 - .006\, p_t - .000002\, y_t + .058\, P_{jt} \\ \qquad (.221)\ (-2.161)\quad (-.624)\qquad\quad (2.955) \end{array}$$

R-Square = .6477.

Adjusted R-Square = .5664.

Durbin-Watson D Statistics = 1.536.

As shown above, the price variable has the correct sign and is significant at the .05 level. The income variable, on the other hand, has a negative sign, implying that kerosene in Saudi Arabia is an inferior good. The effect of income increases or decreases on kerosene consumption is very small and this is why this variable is not significant. Another factor that may cause income not to be significant is the difference between urban and rural population. The price of natural gas, as a substitute product for kerosene, has the correct sign and is significant at the .01 level. R^2 and $\bar{R}^2$ are fairly good indicators for the fit of the kerosene equation. In this case, R^2 implies only 65 percent of the variation on kerosene consumption; this is explained by the explanatory variables in the equation. This suggests that other explanatory variables are not included in the above specification. Consequently, several attempts at estimating the above equation were performed. A different estimate using static or dynamic function was performed, with the inclusion of electricity price and/or the number of buildings constructed. The results were not qualified to be reported in this dissertation. The value of the Durbin-Watson D statistic lies in the inconclusive region and autocorrelation can not be determined at 5 percent level of significance. Therefore, the Cochrane-Orcutt procedures were used to correct the serial correlation that may exist. The following results were obtained:

$$x_t = .0388 - .0057p_t - .000002\, y_t + .056\, P_{jt}.$$
$$(.239) \quad (-1.896) \quad (-.606) \qquad (2.659)$$

As is shown, the price variable has the correct sign and is significant at the .10 level. The income variable, on the other hand, has a negative sign, implying that kerosene is an inferior good. It is not significant. The price of natural gas has the correct sign and is significant at .05 level. R^2 and $\bar{R}^2$ are .61 and .65 respectively. It should be mentioned that no big change in the estimated coefficients occurred. It is clear that the correction result is worse than it was before. The autoregressive correlation coefficient was not significant.

Therefore the ordinary least square is the best result obtained. The Durbin-Watson statistics obtained by ordinary least square is accepted at the 1 percent level of significance. The autoregressive coefficient is .082, which is small enough to imply that correlation is not a serious problem.

Long run price and income elasticities for kerosene are -.006 and -.000002 respectively. This suggests an inelastic demand with respect to price and income. This also implies that kerosene is an inferior good in Saudi Arabia.

Summary of the Regression Results

The demand equations estimated in this chapter are presented in Table XXVIII together with R^2, $\bar{R}^2$, t, D.W., and Durbin-h. A look at the table highlights the similarities and differences among the three equations. Their structure is quite similar since they were derived under the same economic assumptions. The basic formulation consisted of consumer income, price and a lag dependent variable represented by the partial adjustment specification for gasoline; price and a lag dependent variable represented by the partial adjustment specification for diesel; and price, consumer income, and natural gas price for kerosene equation. In all of the cases, the variables used are those suggested by the consumer theory approach as well as the Saudi Arabian market conditions. In each case, except for income in the kerosene equation, the signs of the regression coefficients were those anticipated. The t-test for the regression coefficients indicates statistical significance at either .0001, or .01, or .05 levels.

All the demand equations presented in Table XXVIII were believed to meet the assumptions required for the use of ordinary least squares

TABLE XXVIII

RESULTS OF THE ESTIMATED DEMAND EQUATIONS

Equation Name	Dep. Variable	Constant	Real Own Price	Real Consumer Income	Lagged Dependent Variable	Real Substitute price	R^2	Adjusted R^2	D-W	D-h	F
Gasoline	x_t	.0921	-.1184***	.07789***	.8545*	---	.9982	.9978	2.592	-1.34	2465.575
		(-.216)	(-2.604)	(2.589)	(29.913)						
Diesel	x_t	1.3105	-.3411***	---	.8089*	---	.94	.93	2.124	-.3	120.11
		(2.4)	(-2.089)		(7.348)						
Kerosene	x_t	.0345	-.006***	-.000002	---	.058**	.64	.56	1.536	---	7.966
		(.221)	-2.161)	(-.624)		(2.955)					

Notes: t-values are in parentheses
* - significant at .0001 level
** - significant at .01 level
*** - significant at .05 level

methodology. The adjusted coefficient of determination for gasoline and diesel are relatively high and for kerosene is fairly good.

As it was indicated, the value of Durbin-Watson and Durbin-h imply that autocorrelation is not a serious problem.

Based on Table XXVIII, the results indicate that prices are a major determinant in all of the equations. In gasoline and diesel, the lagged dependent variable played an important role in their consumption. In gasoline itself, income, price, and lagged dependent variables are very important factors that determine consumption. In the case of kerosene, the income coefficient shows that kerosene is an inferior good in Saudi Arabia. The price of natural gas coefficient implies that kerosene is being substituted by natural gas in the Saudi Arabian market, particularly in urban areas.

Briefly, the following general conclusions can be drawn from the estimated results:

(1) Regardless of the petroleum products considered, the prices have the expected negative signs and are significant in all cases.

(2) The income in the case of kerosene has a negative sign which implies that kerosene is an inferior good in Saudi Arabia.

(3) The results of gasoline consumption indicate that income, price, and the lagged dependent variable are very important. All of them have the right signs and are also significant at .0001, or .05 levels. In term of goodness of fit, correlation, significance of the coefficients, and signs, the gasoline equation performs the best.

(4) The static model yielded a poor result in the case of gasoline and diesel. However, it performed well in the case of kerosene. The inclusion of the lagged dependent variable in gasoline and diesel contributed to the high

R-square values. This is proved by testing static equations for gasoline and diesel.

(5) R-square as well as $\bar{R}$-square imply a good fit for all equations.

(6) All price and income variables are inelastic except that diesel demand is price elastic in the long-run.

Comparison of Price and Income Elasticities With Other Studies

It is now of some interest to compare this study findings to those found in the literature that was reviewed earlier. Table XXIX represents a summary of the elasticities of the fuel refined products estimated in this chapter and the elasticities of these products estimated elsewhere. Looking at the table, a brief discussion deserves to be mentioned.

The estimated elasticities for gasoline consumption in Saudi Arabia can be compared to those presented in Table XXIX. The short-run price elasticity estimate for gasoline in Saudi Arabia is exactly the same as the Pindyck estimates for Brazil and Mexico. It does not deviate too much from the Pindyck estimates for Greece, Spain, and Turkey and from the Pagoulatos estimates for the United States. Short-run price elasticity for gasoline in Saudi Arabia is much larger than the Kainian estimate for Iran. In terms of magnitude, all of the estimates presented in Table XXIX show a non-elastic demand with respect to price. Long-run price elasticity in Saudi Arabia is close to what Pagoulatos estimated for the United States, using a dynamic functional form. Our estimates for long-run price elasticity for gasoline differs from Pindyck and Pagoulatos by a lesser amount, as compared to Kainain and Totto-Johnson-Fesharaki. Again in terms of magnitudes, all of the long-run price elasticities for gasoline presented in Table XXIX show a non-elastic demand with respect

TABLE XXIX

PRICE AND INCOME ELASTICITIES OF FIVE ECONOMETRIC STUDIES OF THE DEMAND FOR GASOLINE, DIESEL AND KEROSENE

Name of Study	Gasoline: Price Elsticity SR	Gasoline: Price Elsticity LR	Gasoline: Income Elasticity SR	Gasoline: Income Elasticity LR	Disel: Price Elasticity SR	Disel: Price Elasticity LR	Kerosene: Price Elasticity SR	Kerosene: Price Elasticity LR	Kerosene: Income Elasticity SR	Kerosene: Income Elasticity LR
Pindyck - Greece, Spain (1979) and Turkey Dynamic	-.15	-.41	.74	1.94	---	---	.16	.69	-.089	-.38
- Brazil and Mexico	-.11	-.55	.26	1.22			-.12	-.20	.10	.15
Kainian (1983) dynamic	-.008	-.033	.23	.91	-.05	-.60	-.048	-.24	.20	1.0028
Totto and Johnson (1983) and Totto-Johnson-Fesharaki (1982) Static										
1970-1975	---	---	---	.88	---	---	---	---	---	---
1975-1979	---	---	---		---	-.16	---	---	---	---
1976-1979	---	---	---	1.02	---	---	---	---	---	---
1970-1979	---	-.09	---	---	---	---	---	-.11	---	-.95
Pagoulatos (1974)										
Dynamic	-.102	-.95	.16	1.49	---	---	-4.74	-6.36	.18	.24
Static	---	-.54	---	.07	---	---	---	-3.71	---	.64
Our Study (1987) dynamic for gasoline and diesel and static for kerosene	-.11	-.81	.07	.53	-.34	-1.78	---	-.006	---	-.000002

to price. If we compare short-run and long-run income elasticities for gasoline in Table XXIX, our estimate for Saudi Arabia is the lowest among all of them except in the Pagoulatos estimate for the United States that uses a static functional framework. However, the good in question is a normal good.

The estimated short-run price elasticity for diesel consumption in Saudi Arabia is larger than what Kainain estimated for Iran, although both are inelastic with respect to price. In the long run, price elasticity for gasoline consumption in Saudi Arabia is larger than what has been mentioned by Totto-Johnson-Fesharaki. Diesel consumption in Saudi Arabia is more elastic to its price, as the statistical result shows.

Our estimate of long-run price elasticity for kerosene in Saudi Arabia is very small as compared with the other estimates in Table XXIX even though it is as inelastic as the others. Long-run income elasticity of kerosene in Saudi Arabia is very small and has a negative sign. Our estimate for kerosene implies that kerosene is an inferior good in Saudi Arabia. This result agrees with what Totto-Johnson-Fesharaki found for Saudi Arabia and with what Pindyck found for Greece, Spain and Turkey.

To conclude this chapter, Table XXIX highlights the following facts:

(1) Some similarity exists between our gasoline estimate for Saudi Arabia and other gasoline estimates for other areas.

(2) In terms of magnitude, gasoline is price inelastic in all studies presented in Table XXIX.

(3) Gasoline represents a normal good in all market studies represented in Table XXIX.

(4) Our study shows that diesel is inelastic in the short-run and elastic in the long-run while others show diesel to be inelastic in both cases.

(5) Our study shows that kerosene is an inferior good in Saudi Arabia. This agrees with Totto-Johnson-Fesharaki's results for Saudi Arabia and with Pindyck's results for Greece, Spain, and Turkey. All of the studies in Table XXIX show that kerosene is inelastic with respect to its price.

From this comparison, certain policies that were used in different countries could be helpful in the Saudi Arabian energy market situation.

CHAPTER VI

SIMULATION ANALYSIS AND FORECASTING

In the previous chapter, the estimation of the demand equations for gasoline, diesel, and kerosene was presented. In this chapter, our goal is to establish the predictive ability of the three demand equations in question; that is, to validate the equations by performing historical simulation and future projection of the three petroleum refined products. Our goal is to present some policy issues that may be of interest to Saudi government.

Policy Analysis

Economic planning and policy implications for regional as well as national development are very important. The model formulated in this study is a helpful tool for developing and testing several alternative policies. Potential patterns of present and future development can be discerned. Qualitative and quantitative dimensions of these patterns can be measured and tested by application of the model.

Supply and demand of petroleum refined products in Saudi Arabia are subject to several economic policies which affect the domestic market structure and performance.

Pricing Policies

Pricing is a very important policy tool in the long run; it reflects the cost of the product supplied. The price of a particular form of oil refined products can be used effectively if an appropriate price base is established.

Prices of oil refined products in Saudi Arabia are government controlled at the wholesale and the retail levels. Traditionally, domestic prices have been kept low due to the low marginal cost of crude oil production and refining. However, the prices of oil refined products have been subject to several changes since the beginning of the last decade. Taxes were imposed on oil refined products and cancelled several times whenever the government felt it necessary. Prices were decreased and increased in some periods.

Production Policies

Oil production in Saudi Arabia is affected by the international oil market conditions, OPEC members production policies, and non OPEC members production policies. Oil production in Saudi Arabia had exceeded 9 million barrels a day prior to 1982. In the summer of 1985, oil production had dropped to less than 3 million barrels a day. More recently, the Saudi government announced that it will increase its oil production to 4 million barrels a day. Almost one million barrels a day go to domestic refinery operations in order to satisfy the domestic demand for petroleum refined products.

The Saudi government could implement a supply-demand balancing strategy which consists basically of assigning specific oil resources to the corresponding uses. This could be done by examining the past and present balances which will allow the analyst to determine the evolution of supply and demand within a comprehensive framework, the bottle necks that exist, and how the supply and demand adjust to constraints. Shortages and surpluses could be reconciled by reducing demand through pricing, rationing, or substitution. Briefly, different elasticity measures could be used to formulate different policies and conclusions.

Income Policies

Since the discovery of oil in Saudi Arabia, there have been an enormous amount of personal income changes which are accompanied by changes in the spending and savings stream. For Saudi Arabia, the increase in oil prices and oil production has increased the oil revenue. As a result, the gross national product and per capita income increased. The wage rate has been rising rapidly in both public and private sectors. The purchasing power of individuals is higher and people are enjoying the use, consumption, and services of many different commodities.

Recently, several events affecting oil production have taken place. The international demand for crude oil has been dropped. As a result, oil exports have declined. Revenues to finance development projects have declined and many projects have been cancelled.

To adjust for this current and future economic situation, discretionary and stabilization policies are being expanded. Government spending has decreased and taxes and fees are levied on many products and services. Free enterprise is encouraged and many government programs are under reevaluation.

Export Policies

For a long time, Saudi Arabia has been the largest oil-exporting country. Recently, the country has been adjusting its oil production downward or upward in response to changes in world demand and to maintain a stable crude oil price.

Saudi Arabia could pump more than 10 million barrels a day so the Kingdom can handle any change in the world oil market. A trade off between crude oil export and the domestic demand of crude oil for refining operations is not necessary. Any changes in oil export can be met without any change in the crude oil domestic supply.

Saudi Arabia is pursuing a long run policy to increase its oil refining and manufacturing product for both domestic and export purposes. For this reason, more refineries are under construction and some others are expanding. By expanding refining capacity, Saudi Arabia expects to gain more foreign exchange and more economic and political power in the world petroleum market.

Economic Model and Simulation Analysis

The economic model describes how an economic entity functions under a certain set of assumptions. In Tenbergen's words: "It describes the behavior of the mechanism which the policy makers have to handle or, borrowing a musical metaphor, have to play."[1]

The goodness of an economic model depends on the raw materials to which it is applied. That is the reliability and accuracy of the data. The value of R^2 depends on the assumption that the model has been specified correctly. For example, Granger and Newbold pointed out that if we have a high R^2 value and low D-W statistics, one may conclude that the model may be

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[1]J. Tenbergen. Economic Policy: Principle and Design, (Amsterdam, North-Holland Publishing Co., 1967), p. 6.

misspecified.[2] In this case, system simulation may not give a good result. However, if R^2 is high, one may expect a better simulation performance.

Simulation provides valuable information concerning the model validity and ability. Validation of the model is in fact seeking goodness of fit, i.e. the model can give estimated values for its endogenous variable not far from the actual values. This guarantees consistency of the model. So, simulation is a powerful tool in pure science as well as social science. In economics, simulation is defined as:

> A numerical technique for conducting an experiment on a digital computer which involves certain types of mathematical or logical models that describe the behavior of a business or economic system over an extended period of real time.[3]

In the simulation process, the first step is to formulate and estimate the model to be simulated. This implies that the coefficients of the model to be simulated are known and the value of the exogenous variables are given by prior information. That is, the actual values of those exogenous variables may be used in developing the ex-post simulation or ex-post forecast. Therefore, ex-post simulation, which is also called historical simulation, is a simulation within the sample period. It involves an estimation of the endogenous variables in the model, using the estimated coefficients and the historical values of the exogenous variables. Its goal is to see how close the simulated values of the endogenous variable is to its historical data. This is a useful simulation in policy analysis because it could be used to compare what might have taken place as a result of alternative policies.

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[2]C. Granger and P. Newbold. Forecasting Economic Time Series, (New York, Academic Press, 1977), p. 206.

[3]T.H. Naylor, et al. Computer Simulation Techniques, (New York, 1966), p. 3.

Ex-Post Simulation Results

The three demand equations of the petroleum fuels that were estimated in the previous chapter were used to prepare an ex-post or historical simulation during the observation period 1967-1983. Known historical values of each independent variable were inserted into the estimated demand equation in question and the dependent variables were estimated for each product over the period 1967-1983. Graphic comparisons of simulated demand to actual sales are presented. Each demand equation has been evaluated using tests statistics to assess the validity of the OLS estimator assumptions.

The closer the actual values to the simulated values, the more assurance that the equation in question is a stable description of the demand of the petroleum product in question.

The results of the historical simulation together with the actual values are reported in Figures 5, 6, and 7. As Figure 5 shows, the actual time path of the gasoline consumption has been reproduced rather closely. This is the best simulation graph obtained. Diesel and kerosene show fluctuation over the observation period. Diesel simulation performed better in the beginning and the end parts of the observation period. It has much deviation in 1973-79. In the estimation process, dummy variable techniques attempted to capture structural changes, but the results were not encouraging. In some periods diesel simulation does not capture the turning point. Kerosene simulation is the worst of all. Its simulation deviates too much compared to the other two products. It does not capture the turning point in many periods. The bad simulation results for diesel and kerosene may be due to the nature of the data and model specification. Data accuracy and model formulation reflect the kind of results that are obtained in the estimation and simulation stages.

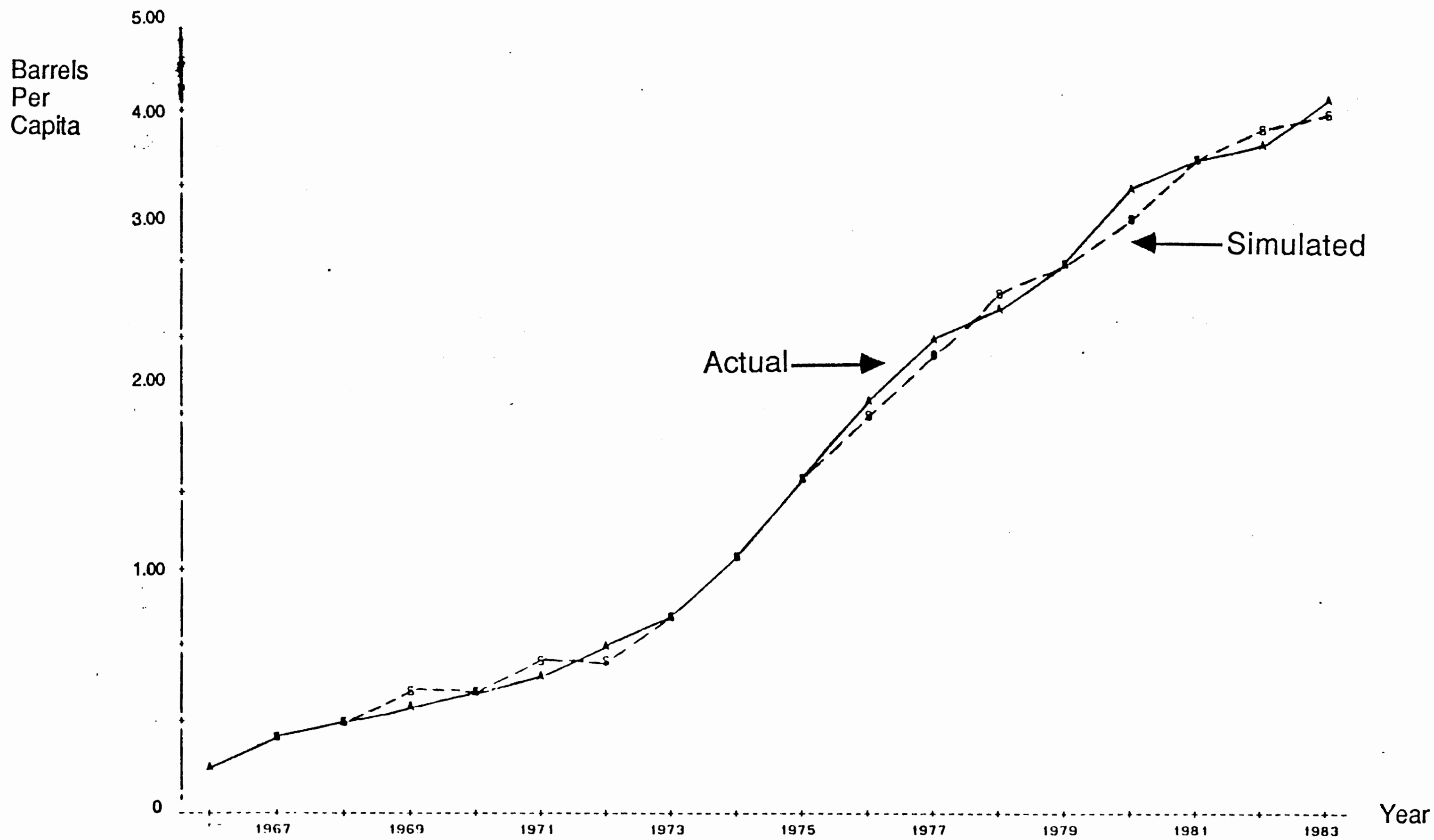

Figure 5. Graph of Simulated and Actual Values of Gasoline Consumption

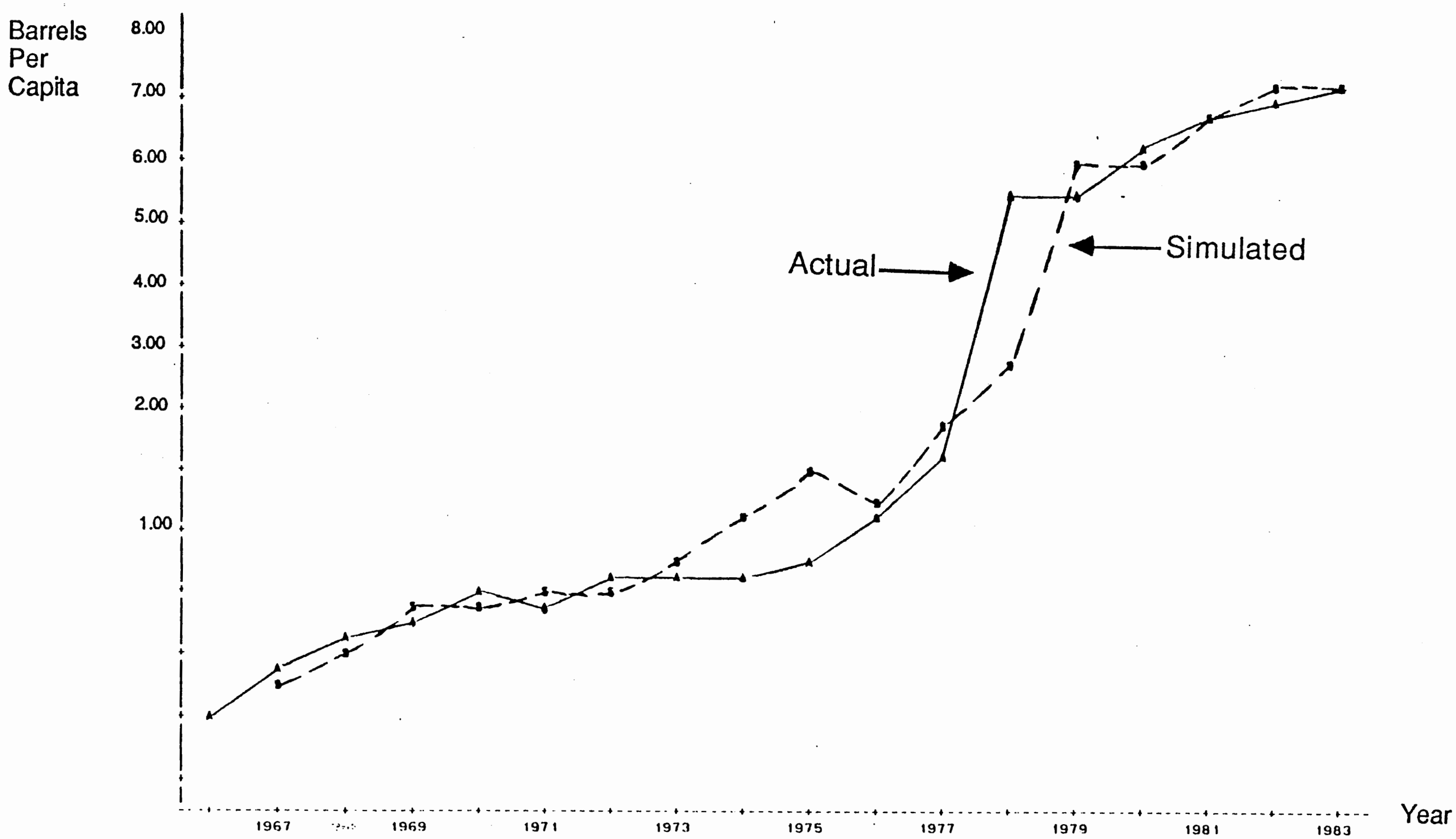

Figure 6. Graph of Simulated and Actual Values of Diesel Consumption

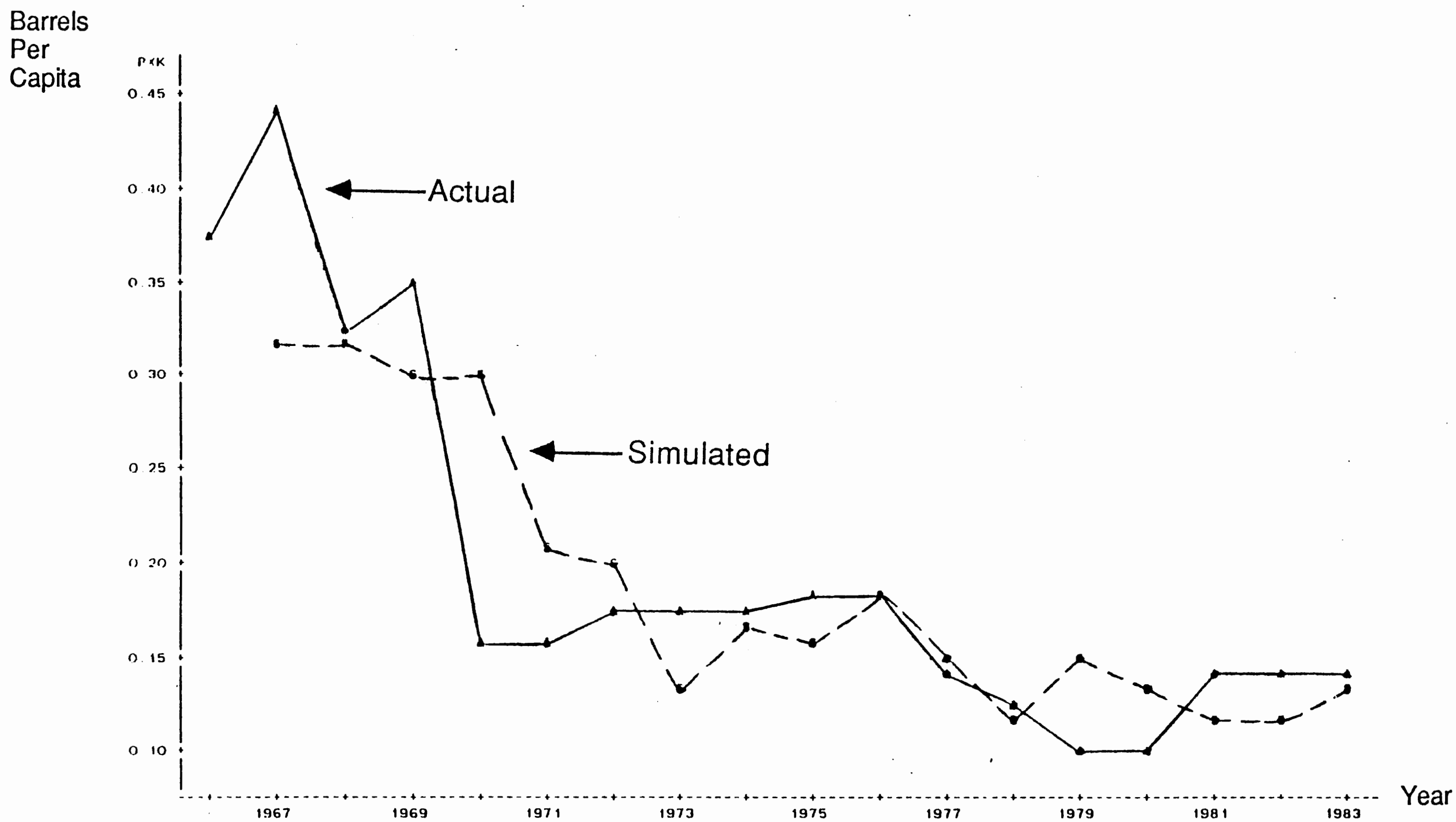

Figure 7. Graph of Simulated and Actual Values of Kerosene Consumption

In addition to the graphical presentation, different statistical tests were calculated and used to measure how closely the simulated values track their actual values over the 1967-1983 period. Those tests include Root Mean Square Error (RMSE), Root Mean Square Percent Error (RMS percent error), Mean Error, and Mean Percent Error. The results of these test statistics are reported in Table XXX. The following formulas were used to obtain these results:[4]

$$\text{RMSE} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(X_t^S - X_t^A)^2}$$

$$\text{RMS Percent Error} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(\frac{X_t^S - X_t^A}{X_t^A}\right)^2}$$

$$\text{Mean Error} = \frac{1}{T}\sum_{t=1}^{T}(X_t^S - X_t^A)$$

$$\text{Mean Percent Error} = \frac{1}{T}\sum_{t=1}^{T}\frac{X_t^S - X_t^A}{X_t^A}$$

where X_t^S and X_t^A denote the simulated and actual values of the dependent variable in the simulated equation.

The Root Mean Square Error is a measure of possible deviation of the simulated values from its actual values over the time path.[5] The Root Mean Square percent error is also a measure of the deviation of the simulated values

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[4]R. Pindyck and D. Rubinfeld. <u>Econometric Model and Economic Forecasts</u>, (New York, 1981), p. 362.

[5]Ibid, p. 362.

TABLE XXX

TEST CRITERIA FOR THE SIMULATION RESULTS

	Gasoline	Diesel	Kerosene
Mean*	1.89	2.95	.185
RMSE	.095	.76	.05
RMS Percent Error	.03	.21	.318
Mean Error*	.002	-.047	.0005
Mean Percent Error	.0014	.026	.06

*Quantity is in per capita term

from its actual values but in percentage terms. The closer the value of Root Mean Square percent error to zero, the better performance of the variable in question. The same logic is true with the mean error and the mean percent error. However, "the problem with the mean errors is that they may be close to zero if large positive errors cancel out large negative errors."[6]

As shown in Table XXX, diesel deviates more than gasoline and kerosene in terms of quantity. In terms of percentage, kerosene has the largest deviation, followed by diesel. Gasoline with the lowest deviation percentage has best results compared to the other two. All three products performed well with the mean error and mean percent error statistics. However, some doubts are registered here, since negative values cancel out positive values in calculating mean error and mean percent error.

Projection of the Demand for Petroleum Fuels in Saudi Arabia

In the previous chapter, the demand for the three petroleum refined products was estimated. In this section these equations are tested with respect to their predictive ability and projections are made under alternative assumptions. Our objective is to provide a basis for the analysis of energy policy by establishing projections of the future consumption of gasoline, diesel, and kerosene. Our projection will cover the period 1984-1988. In a country like Saudi Arabia, with a rapidly changing economy, a long period projection is not appropriate since oil conditions are not clear.

The final demand equation for each fuel and the projected values of each independent variable were used to develop the demand forecast for the three

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[6]Ibid, p. 363.

petroleum products in question. In this case, prices and per capita income play the major role in future projection. Per capita income and/or price, which are the exogenous variables in the three demand equations, are the explanatory variables of fuel demand in Saudi Arabia. Therefore, those should be projected in order to forecast the future fuels consumption.

To develop our 5 year forecast, the following three scenarios were considered:

Scenario I

This scenario is the traditional one. It follows the same pattern that took place during most of the observation period. It assumes the following events will take place:

(1) Prices of the three petroleum refined products and natural gas will increase by 5 percent a year. This is close to the average price change for each product over the observation period.

(2) Per capita income is assumed to follow the historical patterns of the growth rate of the last two decades. That is, per capita income will grow at 8.5 percent during 1984-1988 period.

Scenario II

This case is in between the first scenario and the third one. It presents an alternative result. It assumes the following:

(1) Prices of the three petroleum products and natural gas will grow by 25 percent in 1984 and will not change over the 1984-1988 period. This situation is similar to the price trend in Table XXII. Prices are kept constant for different lengths.

(2) Per capita income will grow by 2 percent less than its historical growth rate. That is, it will grow by 6.5% a year. In this case, income is considered to grow at an alternative rate.

Scenario III

This scenario reflects the present situation in the Kingdom for the fuel oil and natural gas prices. It assumes the following:

(1) All prices will increase by 50 percent in 1984 and will not change over the 1984-1988 period. This is what happened in 1984 when the government increased fuel oil prices by more than 50 percent; these are still maintained until now. The prices under this assumption will be charged over the 1984-1988 period. In this case, the Saudi government wants to increase export of refined products and replace the declining foreign earnings with domestic revenue.

(2) Per capita income will grow by 4 percent less than its historical growth rate. That is, it will grow by 4.5 percent a year over the 1984-1988 period. This reflects the current financial problems that all OPEC countries are facing.

Scenario IV

This scenario assumes the following:

(1) All prices will increase by 5 percent each year.

(2) Per capita income will grow by -6 percent each year. In this case Saudi Arabian income growth is tied to the growth in world oil price. Wharton average forecast of the world oil price growth for the period

1984-1988 is -7 percent.[7] The growth rate in Saudi Arabian consumer price index in 1984 was -1 percent.[8] According to the IMF statistics, the decline trend in consumer price index was followed in 1985 and 1986.[9] Therefore a -1 percent is being used as a proxy for the inflation rate. This is subtracted from Wharton average forecast to put the income figure in real terms.

It should be mentioned that the above four scenarios are very close to the economic situation that Saudi Arabia is facing. Oil price and oil production have been declining since 1982. This is due to the decline in international demand and increase in oil supplies from other countries. Because of this, oil revenues for Saudi Arabia have declined. This results in a decline in per capita income as well as income to finance government expenditures. As a result, the government increased the price of fuel oil and many other products. Taxes and fees were levied on many products and services. If the oil crises continue, Saudi Arabia will be in a much worse situation in the future than it is facing now. Under these conditions, higher prices, taxes, and fees will be charged and the Kingdom development prospects will be in a bad situation.

In order to bring possible relief to the situation, a future forecast for petroleum refined products is performed. The future values of the exogenous variable is presented in Table XXXI. These values are based on the assumptions mentioned above.

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[7]Computed from Wharton Econometric Forecasting Research, March 1987 Forecase, 1987.

[8]Ministry of Planning, Achievement of the Development Planning: 1970-1984, Ministry of Planning, Riyadh, Saudi Arabia, 1985, p. 5.

[9]International Monetary Fund, International Financial Statistics, March 1987, p. 422-423.

TABLE XXXI

PROJECTION OF THE EXOGENOUS VARIABLES: PRICES AND PER CAPITA INCOME UNDER THE THREE SCENARIOS FOR THE PERIOD 1984-1988 IN SAUDI ARABIA (PER BARREL IN SAUDI RIYALS)

	Gasoline Price			Diesel Price			Kerosene Price			Natural Gas Price			Per Capita Income			
Year	5% Growth	25% Growth	50% Growth	5% Growth	25% Growth	50% Growth	5% Growth	25% Growth	50% Growth	5% Growth	25% Growth	50% Growth	8.5% Growth	6.5% Growth	4.5% Growth	-6% Growth
1984	29.86	35.55	42.66	11.12	13.23	15.88	21.54	25.64	30.77	5.00	7.15	9.54	25833.0	25356.8	24880.6	22380.6
1985	31.36	35.55	42.66	11.67	13.23	15.88	22.61	25.64	30.77	5.26	7.15	9.54	28028.8	27005.0	26000.2	21037.8
1986	32.92	35.55	42.66	12.26	13.23	15.88	23.74	25.64	30.77	5.52	7.15	9.54	30411.2	28760.3	27170.3	19975.5
1987	34.57	35.55	42.66	12.87	13.23	15.88	24.93	25.64	30.77	5.79	7.15	9.54	32996.2	30629.7	28392.9	18589.0
1988	36.30	35.55	42.66	13.51	13.23	15.88	26.18	25.64	30.77	6.08	7.15	9.54	35800.9	32620.7	29670.6	17473.7

Fuel prices in Saudi Arabia are the most amenable to direct government control and also the most difficult to anticipate. During the last three years, official fuel prices increased by more than 50 percent. The amount and timing of the changes were subject to economic and political exigencies. Consequently, projection of fuel prices were necessarily tentative.

Table XXXI presents all scenario alternatives for price changes; low, medium, and high. The low price case assumes that the prices will increase by 5 percent each year over the next five years. In Saudi Arabia, the public may prefer this case since it does not have too much impact on their purchasing power. The medium price case assumes a 25 percent increase in fuel prices. This case is presented to represent a possible choice to the government. It is in between the 5 percent increase and the 50 percent case. The high price alternative assumes a price jump of 50 percent, very close to what happened in 1984. This is a government goal. It was intended to improve the economic situation that the Kingdom faced. This case will have a negative impact on the equipment that uses fuel oil and will also increase government revenues. Natural gas prices will follow the same patterns.

Table XXXI presents also all scenario altneratives for income changes. They are also designated as high, medium, low, and negative growth. Those are assumed to be 8.5 percent, 6.5 percent, 4.5, and -6 percent. Per capita income plays an important role in determining the expected volume of petroleum fuels consumption. In recent years, Saudi income from oil revenues has been declining due to oil price decrease. As a result, the government suspended the announcement of its 1986/1987 budgets. Due to these events, income was assumed to follow a declining trend during the 1984-1988 period.

Population is a major factor that influences consumption of fuel oil. Population statistics in Saudi Arabia were gathered in 1962 and in 1974.

Population size in the Kingdom is a controversial issue. There are no reliable figures for the Kingdom population. . Governmental organizations, international organizations, and other agency estimates of Saudi population differ widely. In 1962, the first population census was conducted. The results showed a figure between 3.2 and 3.3 million.[10] In 1974, a second population census was conducted. It showed a total population of around 7 million.[11] The World Bank estimated the Saudi population to be 8.2 million in 1978.[12] Ramon Knauerhase considered the Saudi Arabian population to be between 3.75 and 4.5 million in 1974.[13] The International Monetary Fund estimated the Saudi population in 1980 to be 9.23 million.[14] In 1980 and 1984, the United Nations estimated the Saudi Arabian population to be 9.2 and 10.8 million respectively.[15]

It has been estimated that the second census showed a growth rate between 2.7 and 3 percent.[16] Between 1975 and 1980, the annual growth

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[10]M.S.A. Aljiffry, "Manpower Projection Model for Economic Planning in Saudi Arabia Using Input-Output Technique," (Unpublished Ph.D. Dissertation, Oklahoma State University, 1983), p. 15.

[11]United Nations, 1984 Demographic Yearbook, (New York, 1986), p. 149.

[12]World Bank, 1980 World Bank Atlas, (Washington, D.C. 1980), p. 8

[13]R. Knauerhase, The Saudi Arabian Economy, (New York, 1975), p. 13.

[14]International Monetary Fund, International Financial Statistics: 1985, (Washington, D.C., 1986), pp. 540-541.

[15]United Nations, 1986, op. cit., p. 165.

[16]A. Al-Ibrahim, "Regional and Urban Development in Saudi Arabia," (Unpublished Ph.D. Dissertation, University of Colorado, 1982), p. 62.

rate was reported to be 5.6 percent.[17] The I.M.F. estimated the Saudi population growth rate to be 4 percent.[18] The World Bank estimated this growth rate to be 3.5 percent for the 1970-78 period.[19] The U.N. estimated this growth rate to be 4.1 percent.[20] For the purpose of this section, the International Monetary Fund population growth rate was used in the projections. The IMF estimated that the Saudi Arabian population is growing at 4 percent a year. They estimated the 1984 and the 1985 population to be 11.09 and 11.54 million respectively. Following this trend, the 1986, 1987, and 1988 Saudi-Arabian population will be 12.0, 12.48, and 12.97 million for each year respectively.

Having the values of the determinant variables for the period 1984-1988, we are in a position to use the model to predict the quantity that will be demanded of each petroleum refined product in question. Our projections were maintained by substituting the projected values of the exogenous variables in the three demand equations for the 1984-1988 period. The results of the four scenario experiments are presented in Table XXXII and Figures 8, 9, and 10. Table XXXII shows the possible future demand for gasoline, diesel, and kerosene under the four scenario and population growth assumptions.

Under Scenario I, Saudi consumption of gasoline, diesel, and kerosene is expected to rise from 48.195, 89.156, and 1.476 million barrels in 1983 to 77.041, 125.54, and 5.927 million barrels in 1988 for each product respectively. This implies an average annual growth for the 1984-1988 period

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[17]Ibid, p. 63.

[18]International Monetary Fund, 1985, op. cit., pp. 540-541.

[19]World Bank, 1980, op. cit., p. 8.

[20]United Nations, 1986, op. cit., p. 149.

TABLE XXXII

PROJECTION OF PETROLEUM REFINED PRODUCT DEMAND UNDER THE THREE ATLERNATIVE SCENARIOS FOR THE PERIOD 1984-88 (THOUSAND BARRELS)

	Gasoline				Diesel			Kerosene			
Year	Scenario I	Scenario II	Scenario III	Scenario IV	Scenario I	Scenario II	Scenario III	Scenario I	Scenario II	Scenario III	Scenario IV
1984	54784.6	53564.7	52344.8	54182.2	102360.7	96483.0	90716.2	4946.1	6066.2	7275.0	5033.4
1985	60354.2	58161.6	55622.8	58464.4	111476.4	101782.8	90935.2	5181.4	6266.2	7535.6	5367.3
1986	65880.0	63000.0	59040.0	62052.2	118200.0	107040.0	91800.0	5412.0	6468.0	7800.0	5718.5
1987	71510.4	68140.8	62774.4	64985.1	122803.2	112320.0	93225.6	5665.9	6664.3	8074.5	6093.1
1988	77041.8	73669.6	66795.5	67227.9	125549.6	117508.2	95070.1	5927.2	6861.1	8352.6	6487.5
Average Growth	9.8%	8.8%	6.7%	6.4%	7.1%	5.6%	1.3%	5%	6.4%	8.1%	6%

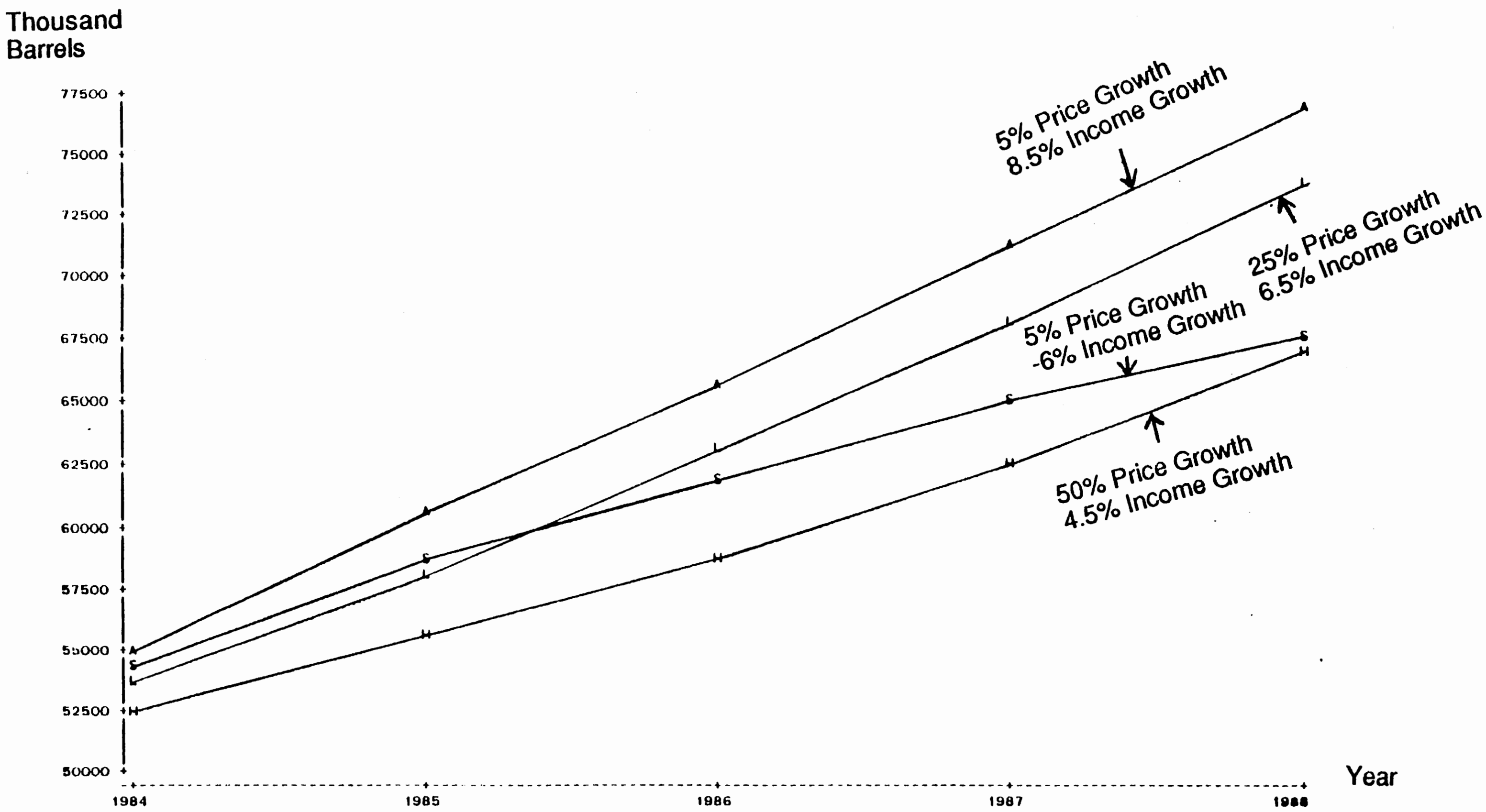

Figure 8. Gasoline Projection

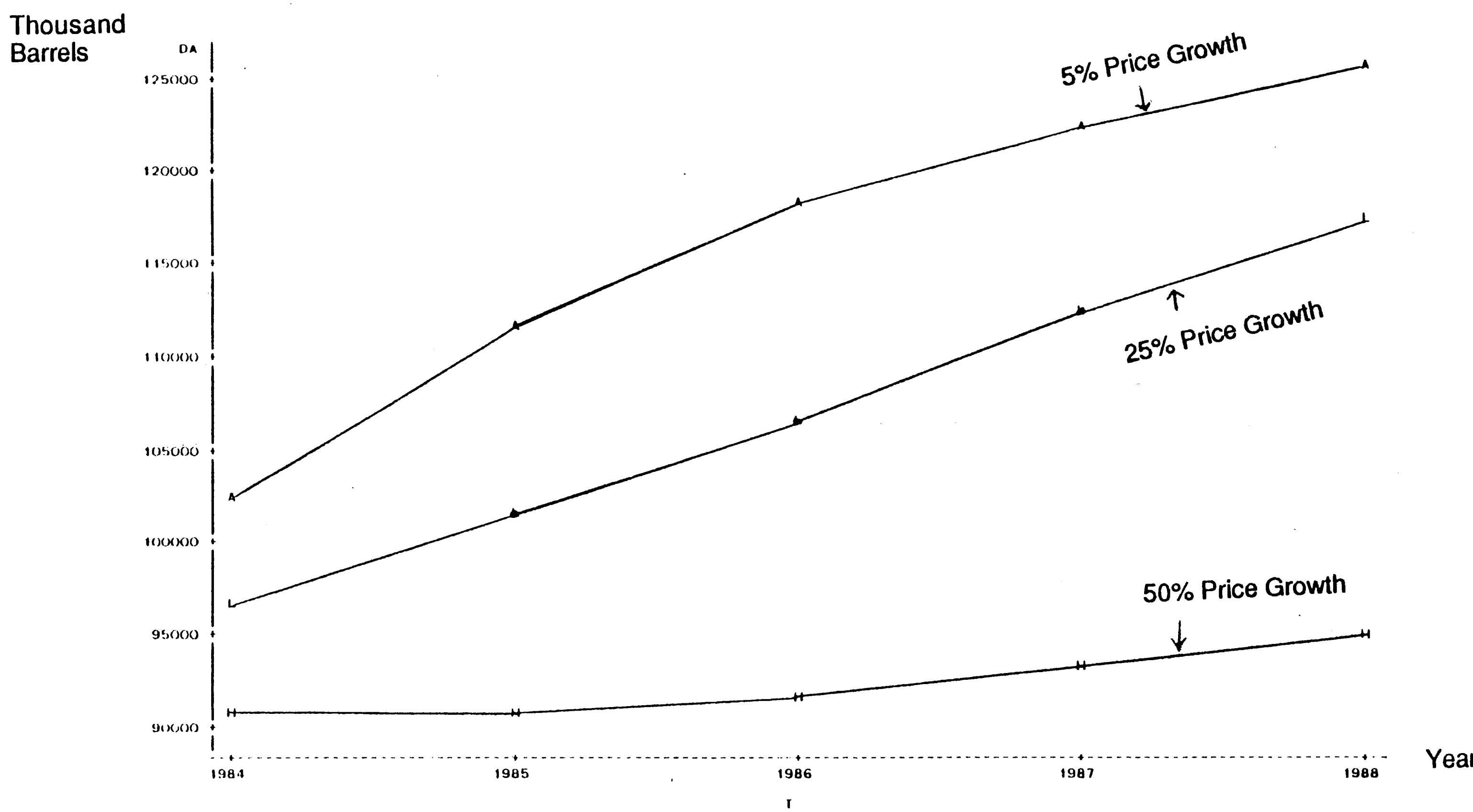

Figure 9. Diesel Projection

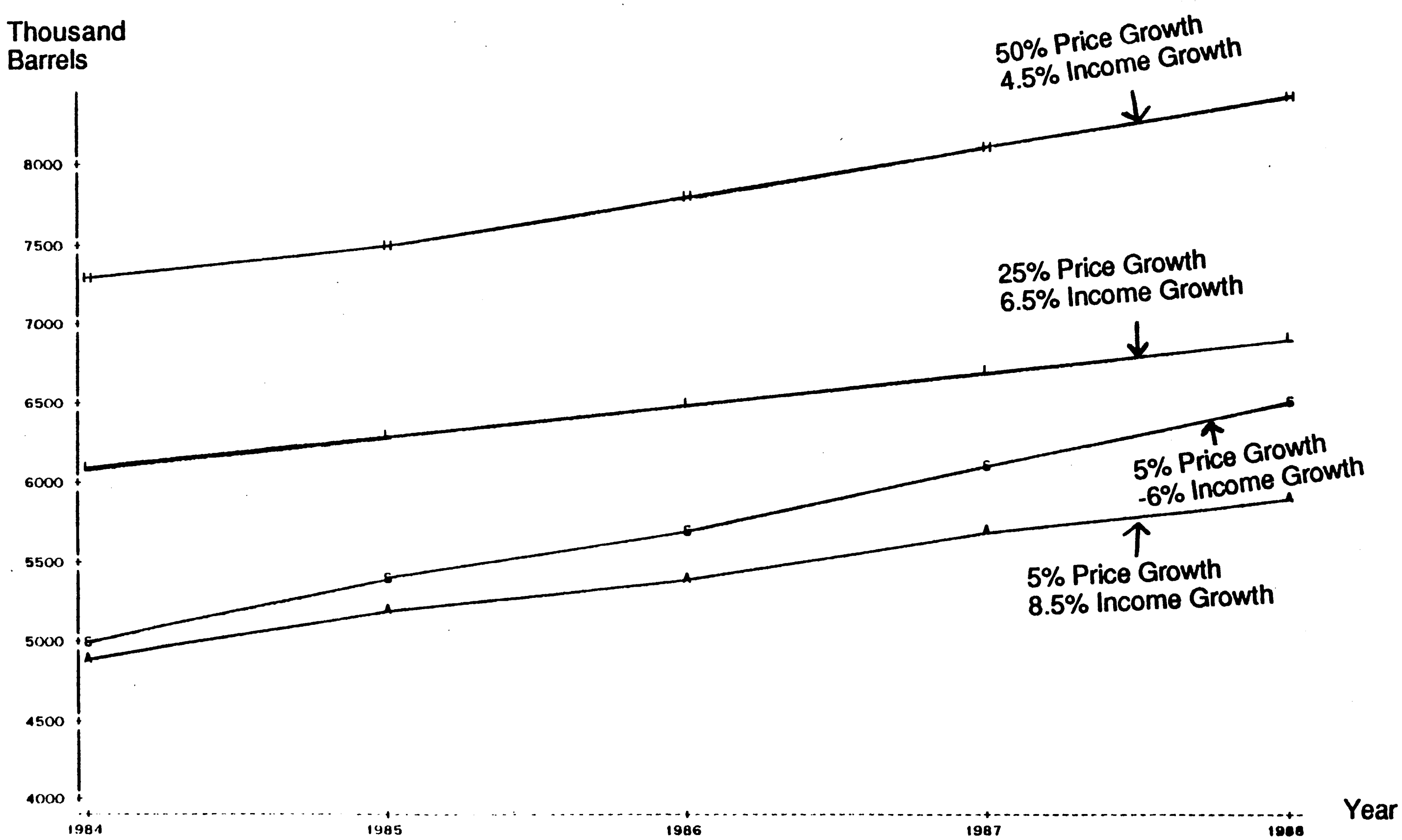

Figure 10. Kerosene Projection

of 9.8%, 7.1% and 5% for each fuel respectively. Under Scenario II, consumption of gasoline, diesel, and kerosene is expected to rise from the 1983 levels to 73.669, 117.508, and 6.86 million barrels in 1988 for each fuel respectively. The average growth under the scenario is expected to be 8.8%, 5.6% and 6.4% for each fuel in question. Under the third scenario, gasoline, diesel, and kerosene consumption is expected to increase to 66.795, 95.070, and 8.352 million barrels in 1988. The growth rates under this scenario are 6.7%, 1.3% and 8.1% for each product. Under Scenario IV, gasoline and kerosene consumption is expected to increase to 67.227 and 6.487 million barrels in 1988. Gasoline and kerosene average growth rate is expected to be 6.4 and 6 percent respectively.

The trend in the demand projection for the three fuels shown in Table XXXII implies that consumption of all of them is increasing over the 1984-1988 period. In the gasoline and diesel case, Scenario III, the consumption is growing slowly, especially in the diesel case. However, Scenario III in the kerosene case, has the highest projected consumption. One may relate this to the fact pointed out earlier about the nature of kerosene, i.e. kerosene is an inferior good in Saudi Arabia.

CHAPTER VII

SUMMARY, CONCLUSION, POLICY IMPLICATIONS AND FURTHER RESEARCH

Summary

This study is concerned with examining the demand situation of three petroleum refined products in Saudi Arabia. It is an attempt to measure the impact of some factors on the consumption of gasoline, diesel, and kerosene. It develops a descriptive and statistical analysis of the energy market in the Kingdom. On the descriptive side, the importance of oil and other energy resources to the Saudi economy are described. On the statistical side, a demand curve equation for each product is developed through the use of econometric technique. This division enables us to disaggregate the analysis of each fuel independently. This provides a better understanding of the market situation of each product in question.

Validation of each equation was achieved by the use of simulation techniques. Historical simulation over the 1967-1983 observation period was carried out. The results were found to be quite satisfactory. In addition, the three equations were used to project the demand of the three fuels for the period 1984-1988. Alternative future scenarios for each product were examined by peforming ex-ante simulation for this period. Different assumptions of prices and income were considered.

The statistical results obtained in this dissertation show that the gasoline equation performed the best of all. Gasoline showed inelastic price and income in the short and long run. Diesel showed unexpected price elasticity in the long run. It was price elastic. Both gasoline and diesel are affected by the previous year's consumption positively. Kerosene results show a very small inelastic price and income elasticities. Kerosene was found to be an inferior good in Saudi Arabia. It was also found that kerosene can be substituted for natural gas.

It was found that the estimated price and income elasticities for the three products in question have some similarities and differences with studies of developed and less developed nations.

In terms of simulation test criteria, gasoline shows a good result with root mean square percentage error. Diesel and kerosene ranked the second and third respectively.

Conclusion and Policy Implications

Petroleum fuel consumption in Saudi Arabia has been increasing rapidly. This trend is a result of subsidized prices and economic development. One objective of this study is to recommend a set of policies that are geared toward curbing the increase in the consumption of petroleum refined products in order to reduce the dependency on oil and consequently improve the energy and economic situations in the Kingdom. Two possible policies could be implemented:

(1) Conservation policy; and,

(2) Development of alternative energy sources.

Although these two policies are concerned with reducing fuel oil consumption and promotion of efficiency and allocation of this energy source, they may affect other economic activities in the Kingdom.

The first policy means that consumption patterns should be changed. To individual consumers, it means a change in their consumption behavior concerning the fuel product in question. This implies reducing driving by car pooling and/or trip saving and also reducing lighting. The government should stimulate and encourage public transport by offering better services and educating the public about the effects. To the industries and public and private enterprises, conservation means an efficient and optimal use of energy as production inputs and products. A policy designed to perceive the value of energy saved as being more than or equal to the cost associated with each person's behavior should be formulated. According to this study's findings, the policy makers in Saudi Arabia can influence energy demand by adapting several measures with regard to conservation policy.

(1) Gasoline demand can be influenced by changing either price and/or income. Since price and income are inelastic in both the short and long run, the percentage change in demand will be less than the percentage change in price and income. Our empirical results on gasoline show that, other things being equal, gasoline demand would decline by .11 percent and .81 percent following a 1 percent increase in price in the short and long run respectively. A 1 percent increase in income yields at most .07 percent and .53 percent increase in gasoline demand in both the short and long run. In 1988, conservation by price and income change constitute the difference between the alternative simulation policies obtained. For example, the difference between scenario IV and scenario III,

432,400 barrels, represents the conservation by price and income changes.

(2) According to our model formulation and findings, diesel demand can be influenced by its price only. In the short run, diesel is price inelastic. This implies that if diesel price increases by 1 percent, demand will decrease by less than 1 percent in the short run. In the long run, diesel is price elastic implying that if price increases by 1 percent, demand will decrease by more than 1 percent. Our empirical results show that a 1 percent increase in price yields at most .34 and 1.78 percent decrease in diesel demand in short and long run respectively. In 1988, conservation by price increase is represented by the difference between scenario II and scenario III. This amounted to 22.438 million barrels in that year.

(3) Kerosene demand can be influenced by changes in its price, income, and the price of natural gas. Both price and income are inelastic in the long run. Our empirical findings show that a 1 percent increase in price yields at most .006 percent decline in kerosene demand. It also shows that a 1 percent increase in income yield at most .000002 decline in kerosene demand. This implies that kerosene is an inferior good. This inferiority is clear in all scenarios. That is, as income increased, directly or indirectly, consumption decreased. In scenario I where income growth is high, consumption is low. In scenario IV where income growth is negative, consumption is high.

The government on the other hand could reduce the fuel oil quantity supplied and could use tax and/or subsidies to improve the energy market function where it is necessary.

A very important policy facing the Saudi Arabian government concerns the most effective and optimal use of its oil reserves. A pricing policy for domestic energy consumption, particularly fuel oil, must be implemented in order to utilize domestic resources efficiently and consequently raise oil revenues. Higher prices for energy products will help reduce the wasteful consumption of those products. Reducing energy consumption through these processes could conserve thousands of barrels of crude oil and/or natural gas, which can either be saved for further consumption or exported to gain more foreign exchange.

The second possible policy can bring about a more fundamental change in the Saudi Arabian energy consumption structure in the long run. It is understood that more exploration to find new reserves of other energy resources are needed to guarantee the expansion of development and reduce the dependency on oil. According to this study's findings, kerosene is being substituted by natural gas. The availability of different energy sources and the substitution possibilities between them will have very important effects on the Kingdom's energy market. It will ease the dependency on oil and support the Kingdom's economic development and security.

To ease the dependency on oil fuels and to increase the substitution possibilities, the Saudi government should consider the following:

(1) Expansion of the solar energy program. In Saudi Arabia solar energy is a potential alternative to reduce the dependency on fuel oil. However, more research is needed in this field.

(2) Introduction of nuclear energy. This should be implemented with caution and after examining this source situation in developed and less developed countries in order to avoid any possible problems.

Its implementation will require a public educational program to represent this source role in the economy.

(3) Expansion of the electric grid facilities so that this source could substitute for other energy sources.

(4) Encourage and support energy research, especially to improve the efficiency in using energy products. An energy department and an energy research institute should be considered very soon.

In brief, available energy sources and the above proposals should be analyzed considering the economic, technological and institutional factors in the Kingdom. More efficient utilization of these sources and more substitution possibilities will help to increase the performance of the present and future situation of the energy market in Saudi Arabia.

Further Research

In developing this dissertation the analysis of the demand are limited to three petroleum refined products. The major reason for this limitation is data availability. If this constraint could be relaxed, the following research could be considered:

(1) A study of the demand for petroleum refined products by each economic sector. This would make it possible to evaluate energy policy in a disaggregate manner and by end users.

(2) A general equilibrium study of what constitutes demand and supply would show market function efficiency.

(3) A study that could include all energy resources would show the overall effect of each one on the others.

(4) A cost-benefit analysis study of the oil industry in order to justify its necessity and importance.

(5) A demand for crude petroleum could be estimated by recognizing the nature of petroleum fuel demand.

In Saudi Arabia, one may list a variety of research opportunities. But the above represent very important topics at the present time.

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