DEMAND FOR COMMERCIAL ENERGY IN KENYA, 1963-1985: A STRUCTURAL INVESTIGATION

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BY

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This thesis is my original work and has not been submitted for a degree in any other University.

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This thesis has been submitted for examination with our approval as University Supervisors.

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ABBREVIATIONS

BP	British Petroleum
EAPL	East African Power and Lighting Company Limited
GDP	Gross Domestic Product
Gwh	Gegawatt hours
I-O	Input-Output
IOI	International Oil Industry
K£	Kenya Pound
KPC	Kenya Power Company Limited
KPLC	Kenya Power and Lighting Company Limited
KPRL	Kenya Petroleum Refineries Company Limited
KVDA	Kerio Valley Development Authority
Kwh	Kilowatt hour
LPG	Liquified Petroleum Gas
MOE	Ministry of Energy
MW	Megawatts
NOCK	National Oil Corporation of Kenya
OLS	Ordinary Least Squares
TARDA	Tana and Athi Rivers Development Authority
TOE	Tonnes of Oil Equivalent
TRDC	Tana River Development Company
UEB	Uganda Electricity Board

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ABSTRACT

Kenya is an oil importing developing country with rapidly increasing commercial energy consumption. She relies on external markets for most of her commercial energy requirements, except hydro and geothermal electricity. The oil price revolutions of the past adversely affected the country's balance of payments, employment, capital formation, capacity utilization and overall economic performance. The demand for commercial energy is, therefore, central to economic development in Kenya.

The primary objective of this study was to investigate the behavioural relationships that constitute the demand for commercial energy in Kenya, and use the results to make policy suggestions. This exercise was deemed necessary in evolving energy demand management strategies which appear imperative for the country.

Ordinary Least Squares methods of estimation were applied on dynamic log-linear demand models for individual fuels using annual countrywide sales data on all commercial fuels and other relevant variables. The data were extracted from secondary sources, and interpolated exponentially to obtain half yearly series for 1963-1985.

The estimation results showed that the demand for commercial fuels in Kenya is generally price inelastic, and responds more readily to income changes than to price changes, in the long-run and the short-run. Changes in the relative importance of different sectors of the economy affect the demand for specific fuels differently, and the efficiency in the use of most fuels either increased or remained high between 1963 and 1985. Economic units in Kenya were not, however, conservational except in the use of coal and domestic electricity.

It is recommended that policy oriented fuel-price increases should be imposed selectively on fuel basis since they can cause difficulties for some fuel users, and that such increases need to be accompanied by other policy measures to make their impact significant. Further, conservation incentives should be given selectively on fuel basis to achieve maximum benefits, and future development strategies should be pursued only after consideration has been given to the energy implications of promoting different sectors of the economy.

CHAPTER I

INTRODUCTION

1.1 Background

Two features epitomize energy use in developing countries. First, they consume more energy as their economies grow due to proliferation of industrial and commercial activities, increased use of household appliances and rapid expansion of energy-intensive transport sector borne out of rural, urban and regional imbalances.[1] Second, commercial sources supply a small but increasing proportion of the total energy requirements.

In 1970, fuel wood accounted for about 70% of Kenya's total energy consumption. This declined to about 60% in 1980. In 1986, Kenya's total gross energy consumption was estimated to be 8.8 million tonnes of oil equivalent (TOE). Non-commercial energy accounted for 74.1% of the total consumption (see Table 1.1).[2] Fuel wood alone accounted for 74% of total non-commercial energy. The consumption of commercial energy, three quarters of which was oil, accounted for only 25% of the country's total energy consumption.

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1. In most developing countries, economic activities concentrate in a few urban areas. This in turn creates the need for an elaborate commuter transport system to cater for the resulting rural-urban, inter-urban and intra-urban travel requirements. See also Robinson (1984: 18 and 19).

2. Commercial energy is defined to be any form of energy with well established markets, and which can be either bought during the normal course of commerce or provided for by a public utility. See also World Bank (1980b: iv).

Table 1.1 Gross energy consumption in Kenya, 1986

Energy Types	Level of '000 toe		Consumption (%)	
Commercial	2,283.5		25.9	
Petroleum		1,653.9		72.4
Coal		67.9		3.0
Electricity		561.7		24.6
				100.0
Non-Commercial	6,519.3		74.1	
Fuel wood		4,827.0		74
Charcoal		1,691.8		26
				100
All	8,802.8			100

Sources: 1. Republic of Kenya (1987). Economic Survey. Government Printer, Nairobi. Table 10.10, p. 138.
2. World Bank (1982).

The consumption of fuel wood, therefore, declined relative to the consumption of other forms of energy. That trend will continue because the contribution of wood-based energy usually falls as incomes increase (Foley 1984: 39). This means that the relative importance of commercial and non-commercial energy in Kenya will be reversed gradually.[3]

1.1.1 Consumption of Commercial Energy

Kenya's consumption of fossil fuels increased from 173,000 to 1.7 million tonnes between 1963 and 1981, but stagnated afterwards. Total consumption of petroleum

[3]. With more income, people can use more household appliances with cleaner, more efficient, and convenient energy.

products increased at 5.5% p.a. during 1963-1972; 1.8% during 1973-1982; and 4.6% during 1983-1986.

Table 1.2 Growth rates in the consumption of petroleum products

Product	Growth rates (% p.a.) 1963-1972	1973-1982	1983-1986
LPG[1]	21.1[2]	6.4	6.6
Motor spirit[3]	7.3	1.7	4.7
Aviation Spirit[3]	-8.3	1.2	0
Turbo fuel	15.3	1.0	1.7
Illuminating kerosene	5.7	5.3	1.0
Power kerosene	-15.7	-37.0[4]	-
Light diesel oil	11.0	4.3	7.3
Heavy diesel oil	7.3	-.6	3.9
Fuel oil	.03	.05	2.9
All	5.5	1.8	4.6

Sources: 1. Republic of Kenya <u>Statistical Abstracts</u>, Government Printer, Nairobi: 1969, 1973, 1976, 1980 and 1986 issues.
2. ____________ <u>Economic Survey</u>, Government Printer, Nairobi: 1985 and 1987 issues.

Notes: 1. Liquified petroleum gas.
2. This is an average growth rate for 1968-1972 because LPG was introduced in Kenya in 1968.
3. Consumption of aviation spirit and turbo fuel include consumption by foreign airlines which account for more than 75% of the total consumption of these fuels.
4. This rate is for 1973-1980. Power kerosene disappeared from the market after 1980.

The consumption of most petroleum products increased rapidly between 1963 and 1972. Average annual growth rates ranged from 5.7% for illuminating kerosene to 21.1% for LPG (see Table 1.2). However, the consumption of fuel oil stagnated around 400,000 tonnes while the use of aviation spirit and power kerosene shrank. The rapidly increasing consumption of most petroleum products resulted from the economy's steady growth over 1963-1972. The declining consumption of aviation spirit, however, resulted from the gradual switch from propeller to more efficient jet engines worldwide.

Between 1973 and 1983, the rate of increase in the consumption of all petroleum products slackened significantly. This was a reaction to the rapid escalations in the import prices of crude oil, the subsequent escalations in the domestic prices of the petroleum products, and the resulting economic slow-down. The average price of crude oil imported from the Middle East increased from US$ 2.74 in 1973 to US$ 34.52 in 1981, a twelve-fold increase.[4] Kenya shillings prices increased more due to several devaluations.

Table 1.3 shows the Mombasa wholesale prices of some of the major petroleum products used in the country. Though tripling between 1973 and 1982, the price of LPG increased less than those of other petroleum products. The price of illuminating kerosene registered the second slowest increase. It is significant that the consumption of these two petroleum products experienced the highest rate of increase in the same order. Similarly, the prices of heavy diesel and fuel oil increased quickly and their consumption slowly relative to other products during 1973-1982.

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[4]. See Republic of Kenya. Economic Survey. Nairobi: Government Printer, 1983 and 1985 issues.

Table 1.3 Mombasa wholesale prices of petroleum products

Product	Prices (KSh/tonne) 1973	1982	1986	Ratios 1982/72	1986/82
LPG	2,060	6,050	5,893	2.937	.97
Premium motor spirit	1,551	10,116	9,976	6.522	.98
Regular motor spirit	1,468	9,736	9,734	6.632	1.00
Illuminating kerosene	736	4,333	4,011	5.887	.926
Light diesel oil	892	5,886	5,525	6.599	.939
Heavy diesel oil	471	3,666	3,136	7.783	.855
Fuel oil	334	2,419	2,266	7.243	.937

Source: Republic of Kenya. Economic Survey, Government Printer, Nairobi: 1983 and 1987 issues.

Note: 1. Prices include sales tax and import duty.

Between 1982 and 1986, wholesale prices of the petroleum products declined, except for regular motor spirit which remained at the same level. This partly explains the observed general rebound in the consumption of the petroleum products.

Generally, increases in domestic prices of petroleum products did not match increases in the crude oil import prices, with the result that escalations in world oil prices were not passed on fully to consumers in Kenya.

Coal, the other fossil used in Kenya, is consumed by the railways, tea estates, scrap industry and in cement production (Republic of Kenya 1978). In 1973, it accounted for 2.5% of the total commercial energy consumption. Its contributions for 1980, 1982, 1984 and 1986 were 2.7%, 3.6%, 3.9% and 3.0% respectively.[5] In 1983, it accounted for 8.8%

5. These percentages are calculated from figures on total consumption of commercial energy found in Republic of Kenya. Economic Survey. Government Printer, Nairobi: 1983 and 1987 issues.

of total energy use in the industrial sector (Jones 1983).

Most of the recent increase in coal consumption resulted from shifts in the cement industry towards increased use of coal compared to fuel oil. In 1982, for example, the Bamburi Portland Cement factory reversed its oil/coal ratio from 19:3 to 3:17 leading to consumption of 152 tonnes of coal in 1985 (Mureithi, Kimuyu and Ikiara 1982: App. 3).

Between 1963 and 1972, total electricity sales increased at 8.1% p.a.[6] Sales to industrial and large commercial consumers increased most rapidly at 11.3% p.a. followed by sales to the domestic and small commercial consumers at 7.3% p.a. Sales to special contracts and off-peak water heating and pumping increased at 6.6% and 5.7% p.a. respectively (Table 1.4).

Table 1.4 Growth rates of electricity sales to different consumer categories (% per annum)

Consumer category	Average annual rates of growth 1962-1972	1973-1982	1983-1986
Domestic (and small commercial) consumers	7.3	6.3	8
Industrial (and large commercial) consumers	11.3	9.1	8.8
Off-peak (water-heating and pumping)	5.7	-.7	-.5
Street lighting	1.9	-.06	-7.7
Special Contracts	6.6	-	-
Total	8.1	7.8	8.2

Source: Republic of Kenya, Statistical Abstract. Nairobi: Government Printer, 1969, 1973,1976,1980 and 1987 issues.
Note: 1. Sales are in kwhs of electricity.

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6. Total electricity sales exclude transmission losses and unallocated demand.

Total electricity sales increased at 7.8% p.a. between 1973 and 1982. However, sales to special contracts were discontinued, while sales for street lighting and off-peak water heating and pumping shrank.[7] Sales to the domestic and industrial consumers continued to increase but at lower rates compared to 1963-1972.

The decline in the rate of increase in electricity sales during the 1973-1982 resulted from reduced economic activity brought about by rapid increases in oil prices. It was also in response to increased cost of thermal generation (and hence increased prices of electricity) caused by increased cost of imported oil. Such cost feeds into the cost and prices of electricity through thermal generation which accounted for 26% of the total installed capacity in 1986.

Recently, total electricity sales have been increasing at 8.2% p.a. Sales to domestic consumers have been increasing at 8% p.a., the highest rate for this category since 1963. The increase in sales to industrial consumers declined to 8.8% p.a. compared to 11.3% and 9.1% for the previous periods. Sales to off-peak water heating and pumping, however, declined from 10 to 8 million kwh between 1983 and 1986. Generally, electricity sales have continued to increase rapidly since 1963.

The relative shares of electricity sold to different regions have also been changing. In 1963, Nairobi and the Mt. Kenya area consumed 70% of the total electric power sold

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[7]. Sales of electricity to special contracts were discontinued in 1978.

in the country, followed by the Coast region with about 21%. The rest of the country consumed only 9% of the total electricity.[8] The consumption was concentrated in urban centres where most of the income earning population and industrial/commercial activities are concentrated.

The same relative regional positions in the consumption of electricity were maintained in 1972. However, those for Nairobi and the Mt. Kenya declined from 70% to 64% while the shares for the Coast and Western regions increased to 24% and 8% respectively. In 1982, Nairobi alone purchased 55.7% of the total electricity, Mt. Kenya area only 3%, Coast region 24%, Western region 12% and Rift Valley more than 5%. The sales of electricity to the Western region have been increasing most rapidly raising its share from 4% in 1963 to 14% in 1985. This has resulted from rapid industrialization in the region.

1.1.2 The International Oil Industry (IOI)

It has been shown that three quarters of all the commercial energy used in Kenya derives from imported oil. In addition, there are 7 subsidiaries of multinational companies importing and processing crude oil and distributing petroleum products in the country. One quarter of the total installed capacity for electricity is oil-based. Thus, Kenya relies heavily on the international oil markets for most of its commercial energy requirements. Understanding the character of the international oil

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[8]. These percentages are calculated from figures on electricity sales obtained from Kenya Power and Lighting Co. Ltd. Directors Reports and Accounts. Various issues.

industry, therefore, forms part of the background for analysing the demand for energy in Kenya.

In the past, the IOI was highly concentrated with only 7 multinational oil companies controlling the operations in the industry.[9] In 1950, these companies controlled 55% of the world's crude oil production, 75% of the refinery operations, 60% of the global fleet of tankers, and 100% of the network of pipelines (Stevens 1984). By 1970, their control over crude oil production had increased to 90% of the production outside the Communist block and North America.

Prior to 1973, the oil companies were integrated both vertically and horizontally. They held joint ownership of the main operating companies and enforced their community of interests through a series of agreements.[10] Under this arrangement, most crude oil moved down the integrated structures. There was therefore no market for crude oil as such, which was discouraged because of possibilities of promoting competition in downstream operations.[11]

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9. The seven oil majors include British Petroleum, Royal Dutch Shell, Standard Oil of New Jersey (Exxon), Standard Oil of California (Chevron), Texaco, Gulf and Mobil. In addition there are other large companies whose operations are more restricted geographically. These include the French Elf, Aquitaine Francaise des Petroles (Total), the Italian Eute Nazionale Idro Carburi (Agip) and Occidental Petroleum. These are, however, not considered as oil majors (Deese and Nye 1981).

10. Some of these agreements included the APQ in Iran, the 5/7th rule and its successor in Iraq, and the "Dividend Squeeze" on over lifters in Saudi Arabia (Stevens 1984: 12).

11. In the literature on the IOI, a distinction is usually made between upstream operations which include prospecting, exploration, drilling and crude oil production and downstream operation which include refining, distribution, retailing and establishment of petro-chemical

Integration was boon for the oil companies because it permitted risk pooling and transfer pricing, and forestalled the tendency towards over production.

In the 1960s, small independent oil companies made their debut to the IOI by obtaining crude oil from newly opened producing areas. About the same time Algeria, Libya, Nigeria and United Arab Emirates started exporting crude oil independently. Other countries set up national oil companies to market crude oil, and in the scramble for crude oil that followed the first crude oil price revolution of 1973, Iraq, Kuwait and Venezuela cut down crude oil supplies going to the oil companies.[12] Nigeria nationalized British Petroleum operations and Iran started to sell its crude oil to third parties. Subsequently, most crude oil producing countries took complete control over the production of crude oil and started integrating downstream.

As the de jure control of crude oil production changed from the oil companies to the oil producing countries, the original agreements became defunct. After the Iranian Revolution of 1978, oil producing countries cancelled the long term supply contracts with the oil companies in preference to short term contracts and spot sales. By 1982, the oil companies handled less than 20% of the world's total

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industries.

[12]. This meant revocation of the arrangements that made it possible for the oil majors to retain crude oil either as equity or buy-back from the countries on whose behalf they produced. Most of the revocations were championed by the Arab members of OPEC for whom the Arab-Israeli war provided a convenient excuse to restrict supply to pro-Israeli importers. OPEC membership includes Algeria, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela.

crude oil and obtained only 30% of their crude oil supplies in preferential contracts compared to 90% in 1970 (Stevens 1984: 18).

One consequence of the destruction of the original structure of the IOI was the creation of uncertainty in the industry. In particular, the IOI became more susceptible to inventory cycles that characterize other commodity markets. A byproduct of this was the creation of the crude oil spot market, which is a mechanism for balancing divergences between supply of and the demand for crude oil. Such divergences became common after the destruction of the integrated structures and their system of checks and balances.

The spot market handles only a small proportion of internationally traded oil.[13] Because of its role as a marginal supplier, however, its impact on crude oil prices tends to be significant. Changes in the prices of spot crude oil sales are a barometer for the extent of the market instability. In addition, the presence of the spot market ensures a proper market for crude oil with actual prices. It also gives room for more participants in downstream operations in the industry, leading to increased competition in petroleum products markets.

1.1.3 The Market for Commercial Energy in Kenya

There are seven subsidiaries of international oil companies importing and/or refining crude oil, and

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[13]. The spot market never accounted for more than 6-8% of the world's total oil trade (Robinson 1982).

distributing petroleum products in Kenya.[14] Some of these have also been involved in oil exploration either individually, jointly or as consortia. In 1959, the Kenya Oil Company, a local private oil company trading as Kenol, was incorporated to sell petroleum products. Until recently, it relied on the international oil companies for its supplies.[15]

A new entrant in the local oil market is the National Oil Corporation of Kenya (NOCK) established under the Private Companies Act Chapter 486 of the Laws of Kenya. It is a wholly Government owned corporation which was found necessary because of the international oil companies' inadequacy in ensuring availability of petroleum products at affordable prices.[16]

There are, therefore, 8 private companies and one public corporation involved in the oil market in Kenya. These are complemented by the Kenya Petroleum Refineries (KPRL) which processes all the crude oil imported into the country,[17] and the Kenya Pipeline Company which delivers the

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14. These include British Petroleum (Kenya) Ltd.,Caltex (K) Ltd. Kenya Shell Ltd., Total Oil (Kenya) Ltd., Esso Standard (Kenya) Ltd. and Kobil (Kenya) Ltd.

15. This arrangement was unfavourable for Kenol which had to close down most of its retail stations in the 1970s because it could not obtain supplies of petroleum products from the international oil companies.

16. When fully operational, the NOCK is expected to import about 50% of the total oil imports. It will not enter the retail market, but will sell processed products ex-refinery to the oil companies and other bulk buyers.

17. The KPRL is designed to process 4.8 million tonnes of oil per year. It is jointly owned by British Petroleum, Royal Dutch Shell, Esso, Caltex and the Kenya Government. It began operations in 1963.

refined products from Mombasa to up-country stations.[18] The oil market is therefore oligopolistic.

The Kenya Power and Lighting Company (KPLC) buys electricity in bulk from other generating companies and distributes it to all consumers across the country. It also generates its own electricity and manages all the power stations owned by Kenya Power Company (KPC), the Tana River Development Company (TRDC), the Tana and Athi Rivers Development Authority (TARDA), and the Kerio Valley Development Authority (KVDA).[19] The electric power market is therefore monopolistic.

The petroleum products and electricity sold in Kenya are subject to maximum price controls. Electricity is priced in accordance with the Electric Power Act which empowers the KPLC to prepare price proposals for consideration by the Government. Up to 1979, the electric power tariff was designed to generate an 8% annual return on all KPLC's assets. Since then, however, tariffs have been based on estimated electric power development cost.

The Ministry of Energy (MOE) prepares price revisions

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[18]. The Kenya Pipeline Co. started operations in 1978 with an initial capacity of 1.2 million tonnes p.a. The pipeline links Mombasa and Nairobi though the company plans to extend it to Kisumu and Eldoret.

[19]. The KPLC is partially government-owned. The KPC is wholly government-owned and secures international loans for all major power projects in the country. It owns the Wanjii and Tana hydro-stations with a combined installed capacity of 21.8mw, and imports 30mw from Uganda. The TRDC is also wholly government-owned. TRDC owns the Kamburu, Gitaru and Kindaruma stations with a combined installed capacity of 281mw. TARDA and KVDA are statutory bodies advising and co-ordinating development in their regions. TARDA owns the Masinga station with a designed capacity of 40mw. KVDA is helping develop the Turkwell station.

for petroleum products either out of its own initiative or on request from the oil companies. The prices of petroleum products are based on estimated total costs of crude oil procurement and refining. Consideration is also given to wholesale and retail margins, pipeline tariffs, railage tariff, and a fixed allowance for town delivery (see Appendices A and B1-B2).

Coal prices are not controlled since coal is not marketed in Kenya. Industries import only enough for their requirements. All the coal imported in the country is, however, subject to a 30% import duty, but is exempted from sales tax.

To the extent that the oil industry is oligopolistic and the electricity sector monopolistic, the commercial energy market in Kenya is imperfect.

1.2 The Research Problem

Commercial energy currently contributes only 25% of total energy consumption in Kenya. This contribution is however increasing, albeit gradually, as the country goes through the process of energy transition leading to increased consumption of commercial energy and reduced consumption of non-commercial energy. The rapid rates of increase in the consumption of both petroleum products and electricity recorded since 1963 ensures that commercial energy will occupy an increasingly significant position in the energy sector in Kenya.

Unfortunately, Kenya produces neither oil nor coal,[20] both of which account for more than 75% of all the commercial energy used in the country. The rest comes from electricity. About 25% of the total installed electric power capacity is oil-based and 5% is imported from Uganda. Therefore, more than 82% of all the commercial energy used in Kenya is imported.

Oil exploration has been going in those areas of Kenya with favourable geological formations since 1954 when the first exploration license was issued to BP Shell Petroleum Company (Maquand and Githinji 1980; Senga, House and Manundu 1980).[21] More than 30 years after, there is still uncertainty about the existence of oil reserves in the country.[22] The country's total hydro-electric and geothermal potential is estimated to be 1290mw and 800mw respectively (Republic of Kenya 1985; Ndobi and Bhogal 1980). The consumption of electricity is, however, doubling every 7-10 years, and even if the total estimated domestic electricity potential were exploitable, it would be exhausted within a generation.

Additionally, there has been changes in the IOI which

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20. However, the country has been pursuing a power alcohol programme since 1977. Currently, there are 3 projects with a total design capacity of 80 million litres of alcohol per year. Only the Muhoroni-based bagasse using distillery has been producing power alcohol for blending with motor spirit since 1983. It has an estimated 18 million litres per annum capacity.

21. Only 16 exploratory wells were sunk between 1954 and 1982. However, there has been efforts to intensify exploration activity and attract more participation by oil companies in recent times (World Bank 1982; Weekly Review 1985).

22. There has been some recent public pronouncements which suggest that there are some possibilities of an oil find.

have had undesirable effects in oil importing countries like Kenya. First, the country's oil account, which used to balance, has been in deficit since 1972. Between 1973 and 1974, this deficit jumped from Kenya Pounds (K£) 3.4 million to 33.4 million, and from 47 million in 1978 to 200.1 million in 1981. It has remained around that level.[23]

Second, past crude oil price escalations led to escalation in domestic prices of petroleum products, and made it necessary for the KPLC to introduce a fuel cost adjustment factor in its pricing system to recover the cost of oil products used in thermal generation. This in turn led to increases in consumer prices of electric power which would not have otherwise been experienced. Increases in commercial energy prices cause inflation, and subsequently a reduction in people's well-being.

Third, the crude oil price revolutions affected the country's economic performance. Between 1970-1971 and 1971-1972, Kenya's real monetary GDP (1964 prices) increased by 7.9% and 8.0 % respectively. Over the same period, gross real capital formation in the monetary sector increased by 28.3% and 20.0% respectively. The corresponding growth rates of total wage employment were 7.2% and 4.1%. In the succeeding years, however, these macro-economic indicators showed poor economic performance. Real monetary GDP grew at

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[23]. It is said, for example, that during the 1978-1980 oil price revolution, a supply disruption amounting to less than 9% of total supply caused the oil price to leap from US$ 12.00 to about US$ 40 within only a few months, an explosion of about 330%. Between December 1985 and April 1986, an oil glut of only 5% caused the average price of world spot crude oil to collapse from US$ 22.50 to US$ 11.00 (Amuzegar 1986: 14-15; Salmond 1986: 17-20).

4.4% and 3.8% between 1972-1973 and 1973-1974. Gross real capital formation stagnated between 1972 and 1973, and shrank between 1973 and 1974. Wage employment declined from 826,000 in 1974 to 819,000 people in 1975.[24] Between 1973 and 1974, the country's overall trade deficit jumped from K£ 50 million to K£ 148 million. In other words, the economy performed badly around the first crude oil price revolution.

Poor economic performance was also recorded following the second major crude oil price revolution. GDP grew slowly at 3% p.a. between 1979 and 1980, total wage employment increased only at 2.7% and 2.9% between 1980-1981 and 1981-1982 respectively, and the country's trade deficit increased from K£ 30 million in 1978 to K£ 443.3 million in 1980.[25]

In summary, Kenya relies increasingly more on commercial sources of energy to meet its total demand for energy. The consumption of commercial energy, most of which is bought from outside markets at increasingly worsening terms, has been growing rather rapidly. This has adversely affected the country's balance of payments, capital formation, employment, and overall production. Attempts have been made to reduce the country's vulnerability to changes in the outside energy markets by developing domestic sources of energy. The size of such resources is however

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24. Calculated from data in Republic of Kenya, Statistical Abstract. Nairobi: Government Printer, 1973 and 1976 issues. Poor economic performance was not always entirely the result of high crude oil prices. For example agricultural production fell in 1973/74 due to dry weather.

25. Republic of Kenya. Economic Survey. Nairobi: Government Printer 1980 and 1986 issues.

unknown, and is unlikely to be capable of sustaining rapidly increasing commercial energy consumption. This underscores the need to analyse the structure of the demand for commercial energy in order to increase the capability for evolving appropriate energy demand management strategies.

1.3 Objectives of the Study

The primary objective of this study was to investigate the relationships that constitute the demand for commercial energy in Kenya, and to use the results to suggest policies for improved management of commercial energy consumption. More specifically, an attempt was made in the study to:

(a) identify the principal determinants of the demand for specific fuels,

(b) estimate and determine the specific impact of each of the determinants of the demand for individual fuels,

(c) find whether there has been any conservation and/or changes in the efficiency with which different fuels are used and

(d) use the results to generate some policy prescriptions for regulating the demand for commercial energy.

In the event, answers were sought for the following questions: what are the major determinants of the demand for specific fuels in Kenya and how adequately do they explain observed variations in such demand? What is the exact nature of the short-term as well as the long-term impacts of each of such determinants on the demand for specific fuels?

Are there any manifestations of conservation tendencies and/or improvements in the efficiency with which commercial energy is used in the country?

Answers to these questions were sought with the help of four hypothesis. First, it was hypothesized that the demand for individual fuels is a behavioural phenomenon in which fuel prices, economic activity (measured by either personal incomes or manufacturing output depending on the fuel), lagged consumption of the fuels (to take account of the dynamic nature of energy demand), and the structure of the economy (measured by the relative contributions of different sectors of the economy to GDP) are of primary importance.[26]

Second, it was hypothesized that the demand for commercial fuels in Kenya exhibits lower price relative to income elasticities of demand. Low price elasticities of demand were expected because of a perceived lack of substitutes for most of the fuels, and possible market distortion such as those brought about by price controls. High income elasticities of demand appeared likely because the demand for commercial energy in developing countries is growth-elastic (Foley 1984). Increased incomes allow increased utilization of the more convenient, more efficient and cleaner commercial energy relative to non-commercial energy.

Third, it was hypothesized that there has not been any significant improvements in the efficiencies with which fuels are used in Kenya. It was assumed that significant improvements in energy-use efficiency would require rapid

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[26]. See Chapter III for a theoretical rationalization of the importance of these factors in explaining the demand for energy.

replacement of equipment. Such replacement would require significant increases in foreign exchange expenditure, which would not have been possible at the implied scale due to foreign exchange problems.

Fourth, it was hypothesized that there has been a tendency towards energy conservation in Kenya. This is because of past exhortations for economic units to conserve energy especially after the first crude oil price revolution. Such exhortations are expected to have been heeded to.

Responses to these hypotheses gave insights into the nature of the demand for commercial energy in Kenya which are helpful in designing demand management policy tools. Such management is an integral part of the country's energy sector strategy, and will remain important in the management of the economy for years to come.

A review of the existing literature showed that whereas there has been a number of studies on the energy sector in Kenya, the researchers neither recognized the dynamic nature of energy demand in general, nor addressed themselves to the effects of changes in the structure fo the economy on the demand for energy. This study addressed itself to these issues directly. In that regard it filled a significant gap in the literature and hence fulfilled a primary objective of any study.

1.4 Significance of the Study

For some time now, and especially since the crude oil price revolutions of the seventies, the government has been trying to evolve a comprehensive energy policy to guide activities in the energy sector. That process is far from complete. This study is timely and significant in that it not only makes immediate contribution to energy policy, but also leads to a deeper understanding of the complex behavioural relationships that underlie fuel demand in Kenya. Therefore, the study lays a firmer foundation for future energy demand analysis and policy orientation.

1.5 An Overview of the Methodology

This study identified eleven commercial fuels used in Kenya; namely, motor spirit, gas oil, illuminating kerosene, jet fuel, heavy diesel oil, residual oil, liquified petroleum gas, domestic electricity, industrial electricity, off-peak electricity and coal. Secondary sources were used to assemble annual sales data on the fuels and other relevant variables for 1963-1985. All the data were converted into half-yearly series using exponential interpolation.

The resulting data were then applied on three sets of models for each fuel, the first one capturing the short-run and the long-run effect of prices and incomes on the demand for individual fuels, the second one capturing the effect of changes in the relative importance of the different sectors of the economy on the demand for individual fuels, and a third set constructed in a way that allowed the analysis of changes in the efficiency of fuel use as well as conservation trends. The necessary estimations were carried out using Ordinary Least Squares (OLS) methods with the help of the MUNITAB and LOTUS II computer packages.

1.6 Presentation of the Thesis

This thesis has seven chapters. Chapter I is introductory. In Chapter II, an attempt was made to review the broad types of models that have been used to analyse the demand for energy, including a review of studies and reports on the energy sector in Kenya. Chapter III contains the theoretical foundations of the study and proposes a two-stage optimization procedure that builds on a utilized-capital production isoquant. Subsequently, factors that influence the demand for energy are delineated.

The methods used are explained in Chapter IV, which includes some discussion on the data, the formulation of the fuel demand models, choice of functional forms, and estimation methods. The results are presented and discussed in Chapter V. Chapter VI attempts to extract policy issues from the empirical results including an indication of areas that appeared to merit further research, while Chapter VII draws the study into conclusion.

CHAPTER II

LITERATURE REVIEW

2.1 Energy Demand Models

Econometric models are used in this study to analyse the structural behaviour of the demand for commercial energy in Kenya. For that reason, an attempt is made in this chapter to critically review the broad categories of models which have been used in analysing the demand for energy, including an examination of the literature on the demand for energy in Kenya.

Prior to the oil price revolution of 1973, there were only a few energy demand models (Fisher and Kaysen 1962; Balestra and Nerlove 1966; Balestra 1967; Baxter and Rees 1968). Since then, however, there has been a proliferation of models differing primarily with respect to degree of disaggregation, sections of market analysed, and modelling techniques. This review focuses primarily on the last of these differences.[1]

2.1.1 Input-Output (I-O) Models

The I-O framework was propounded by Leontief (Chiang 1967) in an attempt to put the internal structure of general functiona relationships on a sound theoretical footing. Subsequently, the framework was perfected into textbook material and applied increasingly in analysing economic phenomena.

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1. It is, after all, on the basis of differences in modelling approaches that most evaluation work on energy demand models is broached (Labys 1981; Hawdon and Tomlinson 1982).

including the analysis of energy utilization and requirements. The works by Reardon (1973); Hudson and Jorgensen (1976); Al-Ali (1979) and Park (1982) are examples of its application in energy analysis.

I-O models address themselves to macro-economic linkages and interactions that create intermediate and final demands for goods and services. For this reason, they are useful in estimating total energy requirements as well as in assessing relative energy intensities of final goods and services. They can also be applied in building direct and indirect energy feedback chains for selected sectors as well as for the entire economy.[2]

Al-Ali showed that the demand for energy by Scotland's industrial sector could be represented by:

2.1 $D_{ei} = K_e F_i$

where D_{ei} is demand for energy from the eth source by industry i, K_e is the e^{th} energy row in the Leontief inverse matrix $K = (I-A)^{-1}$ where A is the usual matrix of industrial technical coefficient, and F_i is final demand for the output of industry i.

Park argued that the total energy output of an economy can be estimated using the I-O framework such that:

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2. For example, the work by Al-Ali (1979) focussed on the industrial energy demand in Scotland, while the framework developed by Park (1982) lends itself to application in analysing direct and indirect energy effect for individual sectors as well as for the entire economy.

$$2.2 \quad Q_{\bullet} = Ex + q$$

where $Q_{\bullet}$ is the average energy output of the energy sector, E is matrix of energy coefficients, x is vector of outputs obtained by solving an original matrix of technical coefficients, and q is a vector of constants representing direct energy sales for final demand.

Unfortunately, the I-O framework is based on restrictive assumptions such as fixed technical coefficients, constant utilization shares, and zero-own and cross-price elasticities of demand.[3] It gives no room for substitution possibilities in either production or consumption, and its use tends to be restricted to the short-term only.

It has been argued that in developing countries where official time series data is either unavailable or unreliable, I-O models would be boon (Hawdon and Tomlison 1982). This argument presupposes, however, that input-output tables are easy to generate, which is fallacious.[4] For these reasons, I-O models are inappropriate and their usefulness highly limited.

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[3]. Samuelson (1972) however, showed that if there is only one scarce resource, input/output proportions may remain fixed because of productive efficiency rather than existence of immutable technological requirements. This logic breaks down if there are more scarce resources (Baumoul 1978).

[4]. The Kenyan experience suggests that the production of I-O tables is onerous. There has been only 3 such tables produced for the economy since independence, for 1967, 1971 and 1976. The compilation of the first started in 1968 and was not completed until the fourth quarter of 1972, and the second and third were produced in 1976 and 1979 respectively.

2.1.2 Transcendetal Logarithmic (translog) Models

The translog approach to modelling was developed by Christensen, Jorgenson and Lau (1973) due to dissatisfaction with specific types of production functions such as Cobb-Douglas and Constant Elasticity of Substitution types which were considered restrictive because of additivity and homogeneity conditions. In this sense, the translog approach was an extension of production theory which permitted the derivation of input demand functions, including those for energy. Later, its application was extended to analyse consumer-behaviour (Christensen, Jorgenson and Lau 1975; Pindyck 1979a and 1980).

The main innovation of the translog framework is its exploitation of duality between unobservable production and/or utility functions and costs in the derivation of input demand functions. In production theory, firms are assumed to either maximize output subject to total factor costs or minimize costs subject to a specified production target. In consumption theory, consumers are assumed to either maximize utility subject to a budget, constraint or minimize the cost of meeting a specified utility level. These constitute duality between costs and production/utility functions (Samuelson, 1972).

For example, assume the existence of an aggregate production function that relates output (Q) with four factor inputs namely, capital (K), Labour (L), energy (E) and non-energy intermediate materials (M). For every such production function, there exists a corresponding cost function of the form:

2.3 $C = C(Q, P_K, P_L, P_E, P_M)$

where P_K, P_L, P_E, P_M are prices of capital, labour, energy and raw materials respectively. The inclusion of Q in the set of arguments is in recognition of the fact that costs are dictated not only by the factor prices but also by production targets.

The producer objective under these conditions is to maximize Q subject to a cost constraint. This can be broached in terms of minimizing costs subject to the condition that:

2.4 $Q = (K,L,E,M)$ is held fixed.

For estimation, the cost function represented by equation 2.3 is usually specified as a translog second-order approximation of the form:[5,6]

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[5]. This particular specification has both symmetry and constant returns to scale imposed on it. The approximation can take other forms such as, for example, dropping Q out of the cost function provided necessary separability assumptions are made. See: Hawdon and Tomlison (1982), Berndt and Wood (1975).

[6]. The translog form of the general cost function shown in equation 2.3 is:

$LnC = F(LnQ, LnP_K, LnP_L, LnP_E, LnP_M)$

The specific cost formation shown by equation 2.5 is a Taylor series expansion of the second order. Unfortunately, most of the authors do not show the actual expansion of the general translog cost function.

$$2.5 \quad \ln C = \ln h_o + h_q \ln Q + h_{qq} (\ln Q)^2 + \sum_i h_i \ln P_i + \sum_i \sum_j h_{ij} \ln P_i \ln P_j + \sum_i h_{qi} \ln Q \ln P_i + \tfrac{1}{2} \sum_i h_{ii} (\ln P_i)^2$$

where i,j = K,L,E,M. By differentiating this approximation of the cost function with respect to the input prices, it has been shown (Pyndyck 1979a: 49) that the resulting derivative function has the terms:

$$2.6 \quad \frac{\partial \ln C}{\partial \ln P_i} = h_i + h_{qi} \ln Q + \sum_j h_{ij} \ln P_j$$

According to Shephard (1953) $\partial C/\partial P_i = X_i$ where X_i is the derived demand for input i, and $\ln C/ \ln P_i = P_i X_i/C = S_i$ where Si shows input i's share of total costs. Therefore,

$$2.7 \quad Si = h_i + h_{qi} \ln Q + \sum_j h_{ij} \ln P_j$$

is the share equation that corresponds to the derived demand for input i. The demand function for energy can therefore be estimated by:[7]

$$2.8 \quad S_E = h_E + h_{EK} \ln P_K + h_{EL} \ln P_L + h_{EE} \ln P_E + h_{EM} \ln P_M + h_{Eq} \ln Q$$

This formulation and its variants were used by Berndt and Wood (1975, 1979); Griffin and Gregory (1976); Hudson and Jorgensen (1976); Pindyck (1979a); Cameron and Schwartz

7. Equation 2.8 is obtained by setting i = E in 2.7 and expanding the summation.

(1979); Turnovsky, Folie and Ulph (1982), among others.

The translog framework has also been applied on utility theory by Pindyck (1979a, 1980) and Jorgensen (1977) to estimate the domestic demand for energy. In this regard, the household is assumed to allocate expenditure on competing goods such as durables (N), non-durables (W) and Energy (E). The expenditures on these goods are assumed to be weakly separable.[8] These assumptions permit the construction of an indirect utility function which is dual to the utility function:

$$2.9 \quad U = u(N,W,E)$$

For any set of prices P_N, P_W and P_E, and income M, maximization of the utility function represented by equation 2.9 generates a set of demand function of the general form:

$$2.10 \quad D_i = D_i(D_N, P_W, P_E, M)$$

where i = N, W, E, and D_i represents utility maximizing levels of demand for the three categories of goods. The indirect utility functions for households can then be constructed by replacing N, W, and E with their optimal levels,[9] i.e.

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8. This means that the ratio of the marginal utilities in say commodity group E is independent of quantities of N and W consumed.

9. Prices and income appear as arguments in this general formulation of the indirect utility functions which is homogenous of degree zero in prices and incomes. This suggests that a proportionate change in prices and income should have no effect on optimal consumption of goods, and hence on utility.

$$2.11 \quad V = V[D_N(P_N, P_W, P_E, M), D_N(P_N, P_W, P_E, M), D_E(P_N, P_W, P_E, M)]$$

The indirect translog utility function is obtained as a second-order approximation of the general form of the indirect utility function specified in equation 2.11 and has been shown to take the form (Pindyck 1979a: 30):

$$2.12 \quad LnV = c_o + \sum_i c_i Ln\ (P_i/M) + 1/2 \sum_i \sum_j b_{ij} Ln\ (P_i/M)\ Ln(P_j/M)$$

Given the assumption of utility maximization, budget-share equations are obtained from equation 2.12 by exploiting Roy's Identity (Pindyck 1979a: 28 and 29). The corresponding share-equation for energy, given the above groups of commodities and indirect utility function, is represented by (Pindyck 1979a: 30).

$$2.13 \quad S_e = \frac{P_e E}{M} = \frac{c_e + \sum_i b_{ei} Ln\ (P_i/M)}{c_m + \sum_i b_{mi} Ln\ (P_i/M)}$$

Consistent estimation of the set of share equations generated by Roy's Identity requires exogeneity of prices of goods, which is the main reason for using indirect, rather than direct utility functions.[10]

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[10]. The share equations generated from direct translog utility formulations are functions of quantities of commodity categories which are less likely to be exogenous.

The translog framework has conceptual and applicational problems which reduce its usefulness as a tool of analysis. First, it is based on the assumption that markets are perfectly competitive, which seems hardly the case in Kenya with a large public corporation in the electric power sub-sector and oligopolistic tendencies in the oil sub-sector.

Second, its application requires simultaneous estimation of the complete system of demand equations. The cost/expenditure shares on which such estimation is based must add-up to unity, resulting in disturbance matrices which are singular. Consequently, one of the equations must be initially dropped from the estimations and subsequently recovered from the other estimated parameters. Unfortunately, the results are not insensitive to the dropped equation, and different parameter estimates can be obtained for the same system of equation depending on the dropped equations.[11] There is no objective way of choosing the equation to be dropped.

Third, it has been shown that the parameter estimates obtained from the translog framework are sensitive to the number of arguments included in the original production/utility function, the degree of aggregation, and the way the variables are defined and measured.[12]

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11. This is especially the case when ordinary least squares method of estimation is used.

12. This sensitivity has contributed to the conflicting results on the relationship between energy and other factors (Berndt and Wood 1975, 1979; Mureithi, Kimuyu and Ikiara 1982; Turnovsky, Folie and Ulph 1982; Hawdon and Tomlinson 1982).

2.1.3 Dynamic Models

The relevance of incorporating dynamic elements in the demand analysis was first recognized by Stone (1968) and later propounded and applied in analysing demand for natural gas by Balestra (1966, 1967). Since then, dynamism has continued to pervade energy demand analysis.

Generally, analysts introduce dynamism indirectly in otherwise static demand formulations by either allowing the stock of energy-using durables to change or by incorporating consumer expectations. Since expectations are not estimatable, they are usually substituted out of reduced forms. This results to energy demand equations resembling static formulations except for their inclusion of lagged-endogenous variables on the explanatory side. Typical of this are the works by Uri (1979a, 1979b), Pindyck (1979a) and Kimuyu (1984).

The popularly used adjustment mechanism is:

$$2.14 \quad Q_t - Q_{t-1} = k(Q^*_t - Q_{t-1})$$

where Q, Q* and k represent actual demand, ex ante or desired demand, and coefficient of adjustment, respectively.[13] Substitution of this relationship leads to an ex post demand function with lagged consumption as one of the explanatory variables. For example, if the ex ante demand function is:

$$2.15 \quad Q^*_t = a_1 + a_2Y_t + a_3P_t + U_t$$

where Y_t, P_t and U_t are income, prices and error terms, then

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13. Variations of this adjustment mechanism include $Q_t/Q_{t-1} = (Q^*_t/Q_{t-1})^k$ so that actual demand becomes $Q_t = (Q^*_t)^k \; (Q_{t-1})^{1-k}$

Equation 2.14 can be rearranged to give:

2.16 $Q_t = kQ_t^* + (1-k)Q_{t-1}$

which when added to 2.15 becomes:

2.17 $Q_t = k(a_1 + a_2Y_t + a_3P_t + U_t) + (1-k)Q_{t-1}$

Equation 2.17 can be further simplified to

2.18 $Q_t = a_1' + a_2'Y_t + a_3'P_t + (1-k)Q_{t-1} + U_t'$

where $a_1' = ka_1$, a_2', $a_3' = ka_2$ and $U_t' = kU_t$. This equation differs from static formulations by the inclusion of lagged-values of demand for energy (Q_{t-1}) in the set of explanatory values.

Uri (1979a) showed that dynamic energy demand models can also be derived from energy price expectations rather than adjustment mechanisms. He argued that under conditions of uncertainty, future price changes have permanent and transitory parts. Permanent changes affect all future consumption, but transitory changes, if so perceived by consumers/producers, do not affect behaviour.

The adjustment of prices from actual to expected levels can take the form:

2.19 $P_t^*/P_{t-1}^* = (P_{t-1}/P_{t-1}^*)^r$

where p^* and p are expected and actual prices respectively, and r is the coefficient of price adjustment,[14] showing the

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14. Linearizing equation 2.19 yields

$LnP_t^* - LnP_{t-1}^* = r(LnP_{t-1}-LnP_{t-1}^*)$

in which case r becomes the elasticity, rather than just coefficient, of adjustment.

proportion of price changes which can be considered permanent, while (1-r) shows the proportion of transitory price changes. Specifying an energy demand function in expected prices and other variables as:

$$2.20 \quad Q_t = A(P_t^*)^b \prod_i X_{it}^b e^{zt}$$

where Q_t is quantity of energy demanded, p^*_t is expected energy price, X_{it} are other relevant explanatory variables, z_t is error term and the subscript t indicates current period. Uri showed that the log-linear form of the energy demand function can be obtained by combining equations 2.19 and 2.20 to give:[15]

$$2.21 \quad Ln\, Q_t = hr + brLnP_{t-1} + (1-r)Ln\, Q_{t-1} + \sum_i b_i LnX_{it} - \sum_i (1-r)b_i LnX_{it-1} + U_t$$

where $U_t = z_t - (1-r)\, z_{t-1}$. Thus the inclusion of price expectation leads to the inclusion of not only lagged-values of the dependent variable on the explanatory side but also lagged-values of all the independent variables, implying that all the explanatory variables have a lag-effect on the demand for energy.

Balestra (1967) pointed out that reactions represented by the adjustment mechanisms on which most dynamic demand

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15. The log-linear form of equation 2.20 is

$$LnQ_t = h + bLnP_t^* + \sum_i b_i LnX_{it} + z_t \text{ where } h = LnA$$

functions are based presuppose that stocks can be adjusted continuously. He argued that while this may be true of inventories, it is unlikely to be true of energy-using appliances. This, in his opinion, is because inventory decisions can be made at reasonably close intervals, but decisions on appliances are made once every so many years depending on the life of the particular appliance.[16]

He showed that given an average appliance stock (S) and a rate of stock utilization (k), new demand for energy can be represented by the difference between total demand and committed demand,[17]:

$$2.22 \quad F_t^* = k_t S_t - (1-p)k_t S_t$$

where F_t^* is new demand for energy, $k_t S_t$ is total demand, $(1-p)k_t St$ is committed demand and p is the rate of stock depreciation. For a fixed rate of appliance utilization, the new energy demand becomes:[18]

$$2.23 \quad F_t^* = F_t-(1-p)F_{t-1} = (F_t-F_{t-1}) + pF_{t-1}$$

In words, new demand for energy is the sum of incremental change (F_t-F_{t-1}) and replacement change (pF_{t-1}).

Balestra further showed that the new demand for any fuel, with gas as an example, can be expressed as function

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16. Of course, continuous adjustment can apply to those parts of such appliances which require regular service and/or replacements.

17. Committed to the existing stock of durables.

18. This is likely to be true in the short-run only.

of the relative price of gas and the total new demand for all fuels, i.e.

$$2.24 \quad G_t^* = b_o + b_1P_{gt} + b_2F_t^*$$

where G_t^* is new demand for gas, P_{gt} is its relative price and F_t^* is as defined earlier. But 2.23 implies that G_t^* = $G_t - (1-p_g)G_{t-1}$, which in turn implies that

$$2.26 \quad G_t = G_t^* + (1-p_g)G_{t-1}$$

and hence[19]

$$2.27 \quad G_t = b_o + b_1P_{gt} + b_2F_t - b_3(1-p)F_{t-1} + (1-p_g)G_{t-1}^*$$

where p_g is depreciation rate for gas using appliances. This formulation captures the dynamic processes in the demand for gas, and can be extended to other fuels.

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19. $G_t = b_0 + b_1P_{gt} + b_2[F_t -(1-p)F_{t-1}] + (1-p_g)\ G_{t-1} =$
$b_0 + b_1P_{gt} + b_2F_t - b(1-p)F_{t-1} +(1-p_g)G_{t-1}$

Some attempts have been made to dynamize the static translog models reviewed in section 2.1.2.[20] Pindyck (1979a) discussed two methods of doing so.[21] First, he showed that the translog approximation can be specified in a way that includes lagged-values of prices, quantities or shares. As an example, the indirect translog utility function can be written as:

$$2.28 \quad LnV = h_o + \sum_i h_i Ln(P_i/M) + 1/2 \sum_i \sum_j b_{ij} Ln(P_i/M) Ln(P_j/M) + \sum_i d_i Ln(P_i/M)\, D_{it-1}$$

where D_{it-1} is a lagged-value of either price, quantity or share which is considered exogenous and critical in the determination of current share. Applying Roy's Identity on equation 2.28 yields share equations of the form:

$$2.29 \quad S_i = P_i X_i/M = \frac{z_i + d_i D_{it-1} + \sum_j b_{ij} Ln(P_j/M)}{z_m + \sum_j d_j D_{jt-1} + \sum_j P_{mj} Ln(P_j/M)}$$

where all the variables are as defined earlier.

Second, dynamic adjustments can be introduced directly in the share equation, making possible the application of simple adjustment mechanisms. For example, it can be

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[20]. In their static forms, the translog models assume implicitly that adjustments in energy demand occur instantaneously. Such an assumption is difficult to justify.

[21]. Pindyck (1979a), however, did not apply either of the two methods.

assumed that each quantity adjusts to desired levels in the traditional fashion, i.e.,

$$2.30 \quad X_{it}-X_{it-1} = w_i(X_{it}^*-X_{it-1})$$

where X_{it}^* and X_i^t are desired and actual quantities of energy and w_i is the coefficient of adjustment. This is said to generate indirect translog share equations of the form:[22]

$$2.31 \quad S_i = [z_i + \sum_j b_{ij} Ln(P_j/M)]/[z_m + \sum_j b_{mj} Ln(P_j/M)] + (1-w)S_{it-1}\ (P_{it}/M_t)/(P_{it-1}/M_{t-1})$$

After observing that the disequilibrium in one fuel market generates adjustments on all fuel markets, Berndt, Fuss and Waverman (1977) attempted to estimate a simple Koyck transformation from United States energy data. However, they failed to identify the exact nature of the lag structure, but proposed a further model incorporating increasing marginal costs of adjustment with adjustment coefficients varying inversely with interest rates and marginal adjustments.[23] The model proposed was, however,

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22. The authors do not, however, bother to derive these share equations.

23. Optimal adjustment process for fixed capital based on a quadratic approximation to adjustment costs was shown to be equal to

$$K_t - K_{t-1} = 1/2[i(i^2 - 4b/q_k d_{kk})]1/2 - 1/b_{kk}(h_k + b_{ek}P_e + b_{lk}P_m - V_k - id_k q_k) - k_{t-1}$$

where q_k = net asset price, d = rate of increase of marginal adjustment cost, V_k = cost of using capital series not applied.

A major problem with most dynamic models is that they are based on adjustment mechanisms characterized by constant coefficients of adjustments. Since such coefficients are not derived from optimization theory, their inclusion appears arbitrary as acknowledged by some authors (Hawdon and Tomlinson 1982).

A problem peculiar to the dynamic translog models is the difficulty of specifying a theoretically acceptable dynamic version of the share equations which, together with Roy's Identity, form the basis for the demand equations. This results from the fact that such share equations are affected by prices as well as quantity changes.

Most dynamic versions of the energy demand models include lagged values of the dependent variable on the explanatory side. However, inclusion of lagged values induces severe collinearity between variables in the demand models leading to suspect estimates of the coefficient of adjustment and a reduction in the reliability of test of significance for all estimated parameters (Hawdon and Tomlison 1982: 24).

2.1.4 Other Models

A wide range of other models have been used to analyse energy demand. Of these, the *ad hoc* types, so called because of their total lack of theoretical basis, are the majority. Examples include the works by Kouris (1976); Halvorsen (1975); UK Department of Energy (1978); the

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and b_{ii} are price coefficients from demand function.

Birmingham Energy Model in Carey (1978); and the "time-of-day" electricity demand studies by Atkinson (1978); Granger, et. al. (1979) and Taylor (1979).

Other studies have focussed specifically on the transport sector which is dominated by gasoline as the only fuel. These studies exploit the strong link between fuel consumption and one appliance, the automobile, and take advantage of availability of detailed information on automobile stock levels, sales, and efficiency. Such information is often not available in other sectors. The works of Ramsey, Rasche and Allen (1975); Dewees, Hyndman and Wareman (1975); Tzannetis (1978); Pindyck (1979a); Dahl (1979); Lin, Botsas and Monroe (1985) are examples.

In addition, there are other more complicated optimization and programming models including spatial-equilibrium linear and quadratic models such as those by Cherniavsky (1974) and Kennedy (1974), recursive programming and systems dynamics models such as those by Day and Tabb (1972) and Dartmouth Systems Dynamics Group (1977). Most of these were developed and tested in the United States, but have received little application elsewhere due to their heavy data requirements.

2.2 Energy Sector Studies in Kenya

The literature on the energy sector in Kenya is fairly recent, because public and scholars' interest on energy-related issues developed only recently. Most of the work in the sector is descriptive, focussing primarily on the various sources of energy and recorded trends in energy consumption, and highlighting the extent, source and implications of deficits in the sector. Typical of this are the works by Central Bureau of Statistics (CBS), Republic of Kenya (1978), Schipper (1980), House and Killick (1980) and World Bank (1982).

The CBS report was one of the earliest and contains comprehensive statistical description and summary of the energy balance in Kenya for 1969-1977. The study highlights the dominance of imported oil in the supply side of commercial energy, and contends that such dominance, coupled by high oil prices recorded since 1973, rendered the economy unmanageable.

Reporting on the use and conservation of energy in Kenya, Schipper (1980) disaggregated important energy uses into physical and economic activity levels as well as energy intensities, paying attention to demographic and economic structure of the country. He pointed at the interaction between commercial and non-commercial energy, and asserted that low incomes made it difficult for the average Kenyan to purchase the equipment needed to make use of electricity at the household level. His report contains observations on energy use by industrial, residential, commercial and transport sectors, trends and significance of energy prices, and concludes that while there was evidence of attempts to conserve energy in Kenya, many opportunities remained unexploited.

The government prepared a national report to the United Nations Conference on New and Renewable Sources of Energy held in Nairobi in 1981, which described the main attributes of energy demand and supply in the country, including a discussion of the broad strategies that the government was pursuing in an attempt to manage the demand for energy. The report recommended immediate development of solar and wind energy, creation of special fund to finance the development of new energy technologies, and the encouragement of regional cooporation in tackling energy problems.

In 1981, the World Bank (1982) assessed the energy sector in Kenya to delineate the major policy issues. Deforestation and the burden placed on balance of payments by oil imports were found to be the major problems. The mission recommended encouragement of better mix between imported petroleum products and exports, replacement of thermal power generation by geothermal and hydroelectric generation, increased utilization of coal, stepping-up of oil exploration, and improvement of afforestation efforts and efficiencies of charcoal conversion technologies, wood and charcoal appliances.

Jones (1983) undertook a study on industrial energy use in Kenya based on a survey of 160 firms in 1981. Forty six percent of the firms reported having taken some energy saving measures including process changes, recovery of waste heat, and improvements in electrical efficiency. The study revealed that pulp and paper, glass, rubber products, metal and cement were the most energy-intensive sectors. Some of the firms were found to have substituted imported petroleum for less costly or domestic fuels, and there was evidence of increased utilization of coffee husks, tyre scrappings and wood wastes as energy sources.

A report by House and Killick (1980) considered possible development strategies and their energy demand implications in Kenya. They asserted that an export-led strategy for development would create less demand for energy than an import-substitution strategy since the former would be primarily agricultural and the latter industrial. A basic-needs strategy would generate less demand for energy for specified levels of economic growth.

House and Killick made forecasts of energy demand to the year 2000 by assuming that GDP elasticity of energy demand would increase in the long-run by a maximum of 25% due to expected growth in energy intensive sectors. However, the authors acknowledged the sensitivity of their forecasts to chosen energy demand elasticities and economic performance.

Senga, House and Manundu (1980) reviewed trends in energy consumption in Kenya so as to forecast demand.[24] They used time series data for 1956-1977 to generate price and income elasticities which -- together with assumed ranges of possible economic growth rates -- formed the basis for energy-demand projections.[25]

An attempt was made in the study to disaggregate energy use in terms of sectors and fuels, which showed that transportation consumed about 70% of all petroleum products used in the country. The study also showed declining energy

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24. This study was commissioned jointly by UN Department of Technical Corporation for Development and Kenya's National Council for Science and Technology.

25. Except for motor spirit whose sales records could be obtained from as far back as 1950.

intensity of manufacturing and total production with the former falling by more than 50% between 1954 and 1974.

The authors used a set of static energy demand models to gauge the response of demand for energy to incomes and prices. The models were generally ad hoc except for a brief reference to the technical relationship between energy used and stock of appliances. There was, for example, no attempt to explain why incomes and prices should influence the level of energy demand.

The basic equation for the demand for different fuels was of the form:

$$2.32 \quad D_t = AY_t^a P_t^b e^{u_t}$$

where D_t, Y_t and P_t are energy demand, income and energy prices respectively and u_t is error term. This general formulation was linearized logarithmically and ordinary least squares method used to estimate income and price elasticities. The estimation results were used to generate energy demand forecasts to the year 2000.

By using static models, the authors implicity concentrated their analysis on stock utilization and ignored possibilities of adjustments in the stock of energy using appliances, even when the period under consideration stretched beyond 20 years. This is conceptually misleading in the first instance, and generates short term demand elasticities when applied on time series data. Such elasticities are inappropriate even for medium-term, let alone long-term, forecasting.

The fuel demand functions, specified in a way that restricted them to only two explanatory variables, namely, incomes and prices of the fuel in question, appear to have been misspecified. There is a host of possible socio-economic variables related to the demand for particular fuels which were excluded in the model specification.[26] This suggests that estimated elasticities for individual fuels are likely to have been biased since the price and income coefficients would have mopped-up the effects of related variables not included in the specification.[27] This is a possible explanation for the incredibly high income elasticities of demand for automotive fuels.[28]

A study by Mureithi, Kimuyu and Ikiara (1982) attempted to analyse the impact of increased energy costs on balance of payments, choice of production technology and real incomes in Kenya.[29] Time series information was used to trace the feed-through mechanisms of increased energy costs and assess substitution possibilities between different fuels, and between energy and non-energy factors of production.

The translog framework was employed to estimate cost shares constituting input demand equations. Estimated cross

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26. These include the proportion of people living in the urban areas, the price(s) of other fuel(s) automobiles with current road licenses, gasoline, and volume of air traffic for aviation fuels.

27. For the nature and direction of such bias, see: Pindyck and Rubinfeld (1976).

28. The GDP elasticities of demand for diesel and motor spirit were 1.606 and 1.392 respectively.

29. This study was sponsored by the International Labour Office under its Technology and Employment Programme in 1981/82.

elasticities of demand suggested that labour and energy were complementary in production, but energy and capital were substitutes.

The report revealed possibilities of substitution across different fuels and between energy and capital. The authors contend that it is the direct costs of raw materials, rather than that of energy which increased most rapidly between 1964 and 1976, suggesting that energy was not the major villain of the economic problems that the country was experiencing.

The general shortcomings of the translog approach have already been discussed in section 2.1.2 of this Chapter. In addition, the Mureithi-Kimuyu-Ikiara report failed to incorporate the complete set of homogeneity and conformity assumptions.[30] Such omission is likely to have affected the parameter estimates and led to wrong interpretation of the relationship between energy and other inputs.

Between 1980 and 1982, the Beijer Institute and the Government of Kenya carried out the Kenyan Wood Fuel Project study out of which the current afforestation and reforestation strategy evolved. In addition, the project led to the publication of a number of volumes by the Beijer Institute and the Scandinavian Institute for African Studies

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30. The share equations were of the form:

$$S_i = b_i + \sum_j b_{ij} LnP_j + b_{it} LnT$$

where ij are capital, energy, labour and material and T is time. An important restriction for consistent estimation of these share equation is $\sum_i b_{ij} + \sum_j b_{ij} = 0$

which the authors failed to impose in its entirety.

under their Energy, Environment and Development series.[31] However, the volumes focus primarily on wood fuel and pay little attention to other sources of energy.

There are three studies on the energy sector by Okech (1985, 1986, 1987). The first of these attempts to evaluate the socio-economic and cultural implications of the existing energy procurement, processing and utilization technologies in Kenya. The second is a critical analysis of the energy system in the country, and includes some observations on the energy markets and pricing procedures and their welfare implications, the role of the government in the energy sector, and the evolution and status of energy policy. The third and most recent study explores the global coal supply situation and its implications for coal/fueloil substitution in Kenya. The author submits that there is adequate international infrastructure for coal supply, that there is great potential for coal and fuel oil substitution, and that coal can be used for broadening the country's energy base.

2.3 Conclusion

This literature survey reveals that most analysts failed to place their models on theoretically appealing footing. Some recognized the fundamental link between energy utilization and stock of appliances, and attempted to incorporate dynamic elements in their models to take account of possibilities of stock adjustments. The inclusion of theoretically sound adjustment mechanism, however, has been

31. Examples of such publications are: Beijer Institute and Scandinavian Institute for African Studies (1983); Scandinavian Institute for African Studies (1984).

illusive, with the result that analysts contend with fixed coefficients of adjustment derived from arbitrarily chosen adjustment mechanisms and/or price expectations.

Increasingly sophisticated energy-demand models have been developed. However, it is uncertain whether the results justify the costs (Hawdon and Tomlison 1982). Complex energy demand models have not proved superior to simpler ones. This is especially important in developing countries such as Kenya where inadequate data may, in any case, restrain the extent to which modelling can be pursued.

This study uses fuel-demand models synthesized from other models. However, it differs from other studies by including variables reflecting structural changes in the economy; and sets a new frontier for Kenya by suggesting a theoretical base for identifying important determinants of the demand for fuels and anticipating their impacts. It also breaks the tradition by incorporating adjustment mechanisms, albeit simple, through which explicit analysis of long-term behaviour of fuel demand and estimation of pace of adjustment of individual fuels towards desired levels become possible.

CHAPTER III

THEORETICAL FRAMEWORK

3.1 Two-Stage Optimization

Producing, distributing and consuming goods and services uses energy. Consumers use energy to cook, light homes, heat water and drive.[1] Firms require energy to produce both intermediate and final goods and services. The demand for energy is therefore demand for production, including production during consumption.[2]

In either case, the demand for energy is associated with the production of an intermediate material, exemplified by quantity of process steam with specified physical characteristics, the quantity of automotive power necessary to move a truck of a given weight over a specified distance and the amount of heat necessary to bring one litre of water to boiling point.

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1. It is recognized that consumers' motivation for using energy is different from that for firms. Consumers may be assumed to use energy in such a way as to maximize total satisfaction while firms use energy in such a way as to minimize the total costs of producing goods. In the end however, the two groups satisfy conditions that are very similar. See: Samuelson (1965).

2. A distinction is drawn between production that leads to such final goods and services as are traded-in, and any further processing necessary before final consumption.

This intermediate material is called utilized capital.[3] The production of utilized capital requires the application of industrial, commercial or domestic appliances using suitable fuels. After production, it is used in the production, conveyance and/or ultimate consumption of goods and services.

Recent economic literature shows the existence of a trade-off between initial equipment cost and energy-related operating costs in the production of utilized capital (Berndt and Wood 1979; Ohta 1975).[4] Studies have shown that the initial costs of energy-using equipment vary positively with energy efficiency. Berndt and Morrison (1980) have shown that such trade-off between capital costs and energy-related operating costs necessarily implies a trade-off between capital and energy, and can be captured by specifying a production function for utilized capital (T) in terms of energy (E) and capital (K) such that:

3.1 $T = f(K,E)$

The production function so specified shows the maximum quantity of utilized capital which can be produced with any capital/energy combination.

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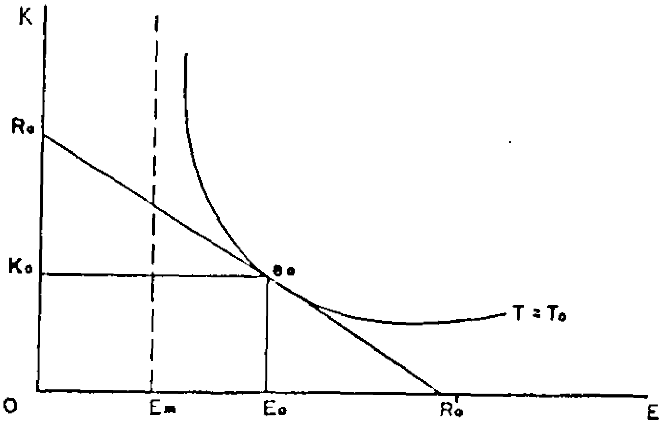
3. The concept of utilized capital was developed and extensively used by E.R. Berndt and others. See: Berndt and Wood (1979); Berndt and Morrison (1980).

4. Analysts have explained the trade-off between equipment and energy costs by ranking alternative energy capital use combinations using life cycle costs. Such trade-off is implicitly assumed to suggest a trade-off between capital services and energy in the production of utilized capital, an assumption which is backed-up by empirical studies (Berndt and Morrison 1980).

Any amount of utilized capital $T = T_0$ can be produced using different combinations of capital and energy. This implies the existence of a utilized capital production isoquant (Figure 3.1). R_0R_0' is the utilized capital iso-cost line and e_0 is the point of optimality with E_0 and K_0 levels of demand for energy and capital respectively.

Figure 3.1 Utilized capital production isoquant



Physical laws dictate that for every task, there is a minimum level of fuel-use below which the task would be impossible. This means that for a specified amount of utilized capital, there is an imperative minimum fuel utilization shown by E_m in Figure 3.1. The utilized capital isoquant approaches such a minimum asymptotically, implying that E_m can only be attained with an infinitely high expenditure on equipment.[5]

5. In particular, the second Law of thermo-dynamics stipulates the theoretical maximum amount of useful work obtainable given some specified quantity of energy. See:

Convexity of the utilized capital production isoquant is guaranteed by the condition of trade-off between equipment and energy. The degree of convexity is determined by the extent of such trade-off, which may be limited to a narrow range in the production map. However, the existence of whatever degree of convexity implies that the marginal productivities of capital and energy are non-negative, and that the two inputs are neither perfect substitutes nor perfect complements within the relevant production range.[6] The utilized capital isoquant is otherwise typical, with a slope that is determined by the ratio of the marginal productivity of energy to that of capital.

A typical equal-cost line in the production of utilized capital can be developed from:

3.2 $P_K K + P_E E = C'$

where P_K and P_E are prices of capital and energy respectively, and C' is total expenditure. Both K and E are composite inputs, each of which is assumed to be weakly separable.[7] This means that their prices can in turn be treated as functions of the individual prices of their

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Berndt and Morrison (1980: 79-97).

6. Since the production of utilized capital is a secondary process necessitated by other primary ones, the relationship represented by the utilized capital isoquant is gross, the net one being empirical. Convexity ensures that the gross elasticities of demand between energy and capital are positive.

7. Weak separability means that the marginal rates of substitution between different types of energy (capital) are independent of utilized capital output and any other inputs external to E (K). See: Berndt and Wood 1979.

relevant components. In particular, the price of energy is a function of the prices of individual fuels. The slope of the utilized capitals iso-cost curve, represented by the line R_0R_0' in Figure 3.1 is given by the ratio of the price of energy to that of capital in that order.

Assuming that economic units wish to either maximize production of utilized capital for a given budget on energy and capital, or minimize the cost of producing a specified amount of utilized capital, production theory suggests that this would be achieved at point e_0 in Figure 3.1. This can be shown algebraically by interpreting the problem as that of maximizing $T = T(K,E)$ subject to the cost constraint $P_K K + P_E E = C'$. The resulting Lagrangean function is:

$$3.3 \quad L_1 = T(K,E) + b(P_K K + P_E E - C')$$

where b is the Lagrangean multiplier.[8]

The first order optimization conditions arising from equation 3.3 are:

$$3.4 \quad \frac{\partial L_1}{\partial K} = \frac{\partial T}{\partial K} + bP_K = 0$$

$$3.5 \quad \frac{\partial L_1}{\partial E} = \frac{\partial T}{\partial E} + bP_E = 0$$

$$3.6 \quad \frac{\partial L_i}{\partial b} = P_K K + P_E E - C = 0$$

8. See: Baumal (1977).

These conditions imply that:

$$b = -\frac{\partial T/\partial K}{P_K} = -\frac{\partial T/\partial E}{P_E} \quad \text{or that:}$$

$$3.7 \quad -\frac{\partial T/\partial E}{\partial T/\partial K} = -P_E/P_K$$

Condition 3.7 states that the production of utilized capital is optimal when the ratio of marginal utilities of both energy and capital is equal to the ratio of their respective prices. This is true of point eo in Figure 3.1.

Alternatively, the problem can be broached by minimizing $P_K K + P_E E$, the cost of producing utilized capital, subject to a given output, T_o. This can be expressed in the Lagrangean form as:

$$3.8 \quad L_2 = P_K K + P_E E + \rho[T(K,E) - T_o]$$

where ρ is a Lagrangean multiplier. Given this alternative formulation, the first order conditions become:

$$3.9 \quad \frac{\partial L_2}{\partial K} = P_K + \rho \frac{\partial T}{\partial K} = 0$$

$$3.10 \quad \frac{\partial L_2}{\partial E} = P_E + \rho \frac{\partial T}{\partial E} = 0$$

$$3.11 \quad \frac{\partial L_2}{\partial \rho} = T(K,E) - T_0 = 0$$

which in turn imply that $1/\rho = -\partial T/\partial K/P_K = -\partial T/\partial E/P_E$

or

$$3.12 \quad -(\partial T/\partial E)/(\partial T/\partial K) = -P_E/P_K$$

Conditions 3.7 and 3.12 are the same, indicating that the optimal point remains the same irrespective of the way the problem is broached.

This shows that to produce T_o of utilized capital, K_o and E_o are the necessary derived demands for capital and energy respectively. It is also observable from Figure 3.1 that optimal energy use E_o is greater than minimum energy requirement E_m. This is because economic units minimize total costs rather than just fuel costs. This distinction is important because it shows the energy efficiency of the system under consideration.[9]

It was stated earlier that utilized capital is produced for the purpose of facilitating socio-economic activity. Using gross output Q as a proxy for such aggregate socio-economic activity, along with appropriate separability assumptions,[10] we can specify an aggregate production function of the form:

$$3.13 \quad Q = Q(T,W)$$

where W is a composite index for all other inputs such as labour and non-energy materials entering the economy's activity processes, and T is as defined earlier.

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9. See: Berndt and Morrison (1980).

10. It is assumed, in particular, that aggregate production is weakly separable and therefore can be summarized by Y = T[(K,E), W] so that marginal rates of substitution within input sub-groups T and W are independent of level of output and quantities of inputs used from other sub-groups.

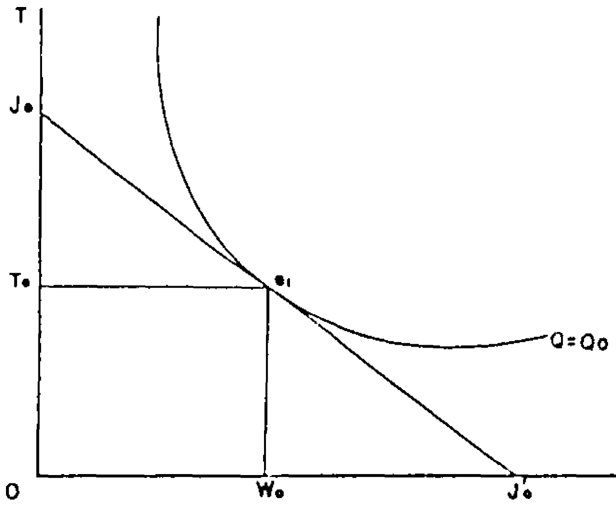
The corresponding cost equation for aggregate production is given by:

$$3.14 \quad P_T T + P_W W = C$$

where P_T and P_W are prices of utilized capital and the labour-materials composite given by $P_T = P_T(P_K, P_E)$ and $P_W = P_W(P_L, P_M)$ respectively.[11] The rest of the variables are as specified earlier. A specific level of aggregate output and the related budget line are shown in Figure 3.2.

Assuming either maximization of aggregate production subject to a cost constraint or cost minimization subject to maintaining a specified level of aggregate output, optimality would obtain at point e_1.

Figure 3.2 An aggregate production isoquant



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11. Ideally, the prices of utilized capital and the labour-materials composite should be denoted by $P_T = P_T(P_{K1}\ P_{K2} \ldots, P_{E1}\ P_{E2} \ldots)$ and $P_W = P_W(P_{L1}, P_{L2} \ldots, P_{M1}\ P_{M2} \ldots)$ since they are composite prices related with prices of different types of equipment, fuels, labour and materials.

At such optimal point, T_0 of utilized capital and W_0 of the labour-materials composite would be used to produce Q_0 of aggregate output.

The logarithmic derivatives along a given aggregate production isoquant define net price elasticities, while gross price elasticities are defined along a production sub-function such as that for utilized capital. It has been shown (Berndt and Wood 1979) that the relationship between net and gross elasticities is given by the equation:

3.15 $c_{ij} = c_{ij}^* + bS_i$

where c_{ij} is the net own/cross elasticity[12] of demand for the aggregate production isoquant $Q = Q_0$, c_{ij}^* is gross own cross elasticity of demand defined along a utilized capital along the aggregate production isoquant T_0, b is own price elasticity of demand for utilized capital along the aggregate production isoquant Q_0, and S_i is the cost share of input i in the production of T_0 of utilized capital.

By definition, $b < 0$ and $S_i > 0$ which imply that $bS_i < 0$ and

3.16 $|c_{ij}| < |c_{ij}^*|$ for $i = j$ and

3.17 $c_{ij} < c_{ij}^*$ for $i \neq j$

---

12. c_{ij} and c_{ij}^* are own price elasticities when $i = j$ and cross elasticities when $i \neq j$, where i and j are inputs.

Equation 3.15 and in-equalities 3.16 and 3.17 have important theoretical implications in the analysis of the demand for energy. First, although energy and other inputs such as capital may be gross substitutes, with a positive gross cross elasticity of demand, the net relationship may be different depending on the magnitude of negative bki term.[13] If this term dominates the positive gross cross elasticity term, then the net cross elasticity is negative, implying that energy and capital are gross substitutes but net complements. This means that the reduction of energy use through increased energy prices could inhibit capital formation and future prospects for growth, compared with other energy-demand-management strategies.

Additionally, inequality 3.16 suggests that the negative net own-price elasticity of demand for energy is always smaller than the gross own-price elasticity. This implies that analyses which are based on gross elasticity alone may over-estimate the net elasticity and hence lead to erroneous policy prescriptions. The set of inequalities further imply that while the gross relationship between energy and other inputs can be theoretically delineated, apriori, the net relationship is empirical.

3.2 Factors Influencing The Demand For Energy

3.2.1 Aggregate Production

A change in the level of aggregate production initiates adjustments which ultimately affect the derived demand for

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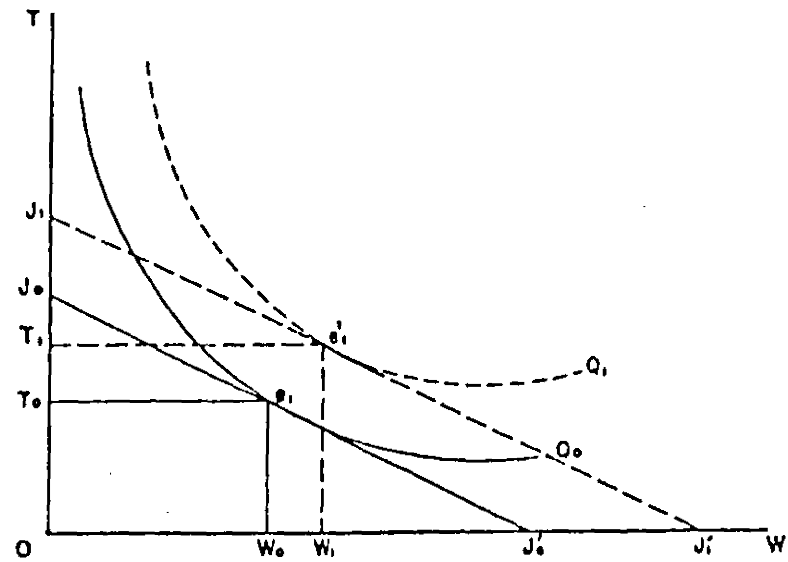
13. This term is also referred to as the 'expansion elasticity'.

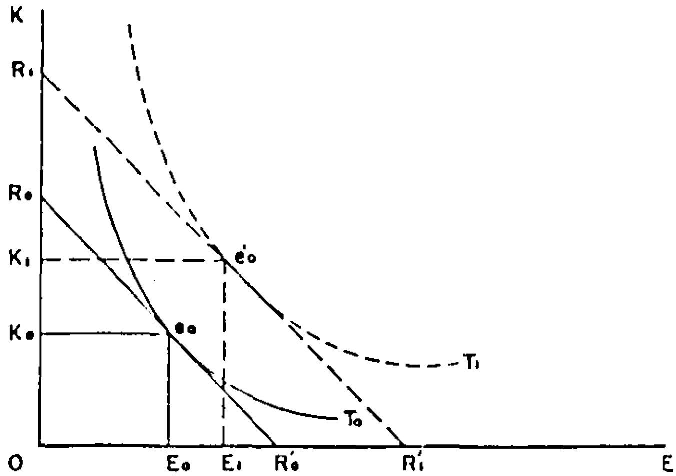
energy. Assume that the economy experiences some significant growth. This would be shown by a new aggregate activity isoquant Q_1 which would be to the right of Q_0 (Figure 3.3).

Figure 3.3 Effect of an increase in aggregate production on demand for utilized capital and labour-materials composite



Point e'_1 is the new point of equilibrium in the aggregate production map with T_1 units of utilized capital and W_1 units of other inputs being used. Specifically, more utilized capital ($T_1 > T_0$) is now required to facilitate the higher level of aggregate output. The utilized capital production sub-system must expand to meet the new level of utilized capital's demand created by the increase in aggregate output. This implies the establishment of a new level of utilized capital output represented by new isoquant to the right of the original (Figure 3.4).

Figure 3.4 Adjustment in the utilized capital production map following an increase in aggregate production



Point e₀' establishes the new point of optimality with respect to the production of utilized capital. This shows that an increase in aggregate production would, among other things, increase the derived demand for energy, since $E_0 < E_1$. The implication is that aggregate production and derived demand for energy are positively related.[14]

3.2.2 Price of Energy-Using Equipment

Assume a fall in the price of capital. This initially makes capital cheaper relative to energy, causing adjustment in the optimal capital and energy requirements in the production of a specified amount of utilized capital. The new point of equilibrium entails enhanced utilization of capital and reduced energy utilization (Figure 3.5).

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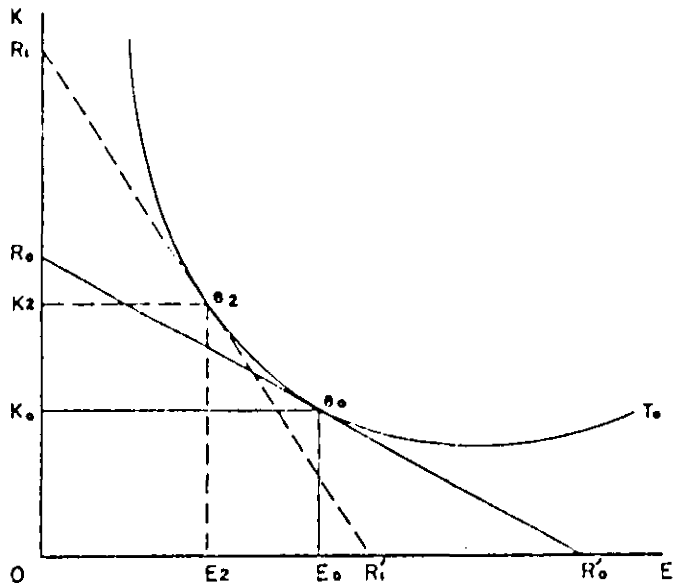
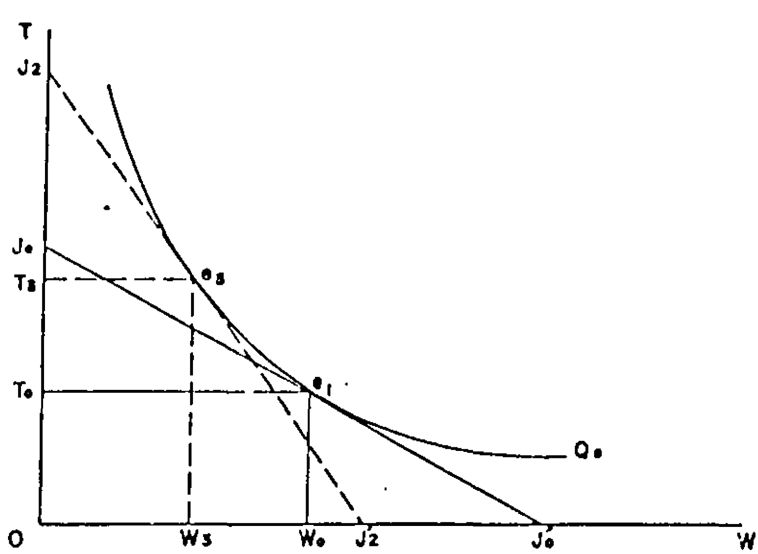
14. In no way does this infer causality. It however confirms a theoretical expectation in the analysis of the demand for normal goods, and suggest that energy can be treated as one such good.

Figure 3.5 Capital-energy adjustment following a fall in the price of capital



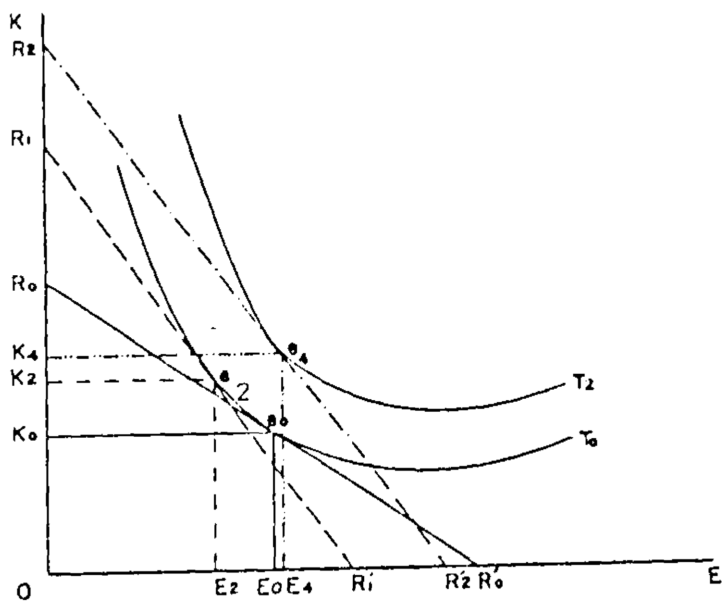
Further, the fall in the price of capital implies a fall in the overall cost of producing a specified amount of utilized capital, stimulating adjustments within the aggregate production map.

Figure 3.6 Adjustments in aggregate production following a fall in the price of capital



Specifically, the reduced cost of utilized capital makes the aggregate budget line steeper, leading to enhanced application of utilized capital (Figure 3.6). The derived demand for utilized capital increases from T_0 to T_3. This in turn creates expansionary pressure on the utilized capital production map to generate the needed increased amount of utilized capital (Figure 3.7).

Figure 3.7 Utilized capital adjustments following a fall in the price of capital



The figure suggests that a general decline in the price of capital exerts a positive expansion effect on the derived demand for both capital and energy. However, the ultimate effect of such decline in the price of capital on the derived demand for energy depends on the relative magnitudes of the two opposing effects, the negative first round substitution effect and the positive second-round expansion effect.[15] In other words, there exists a relationship between derived demand for energy and the prices of energy using equipment. The direction of that relationship is, however, difficult to determine apriori.

3.2.3 Price of Energy

Assume a general increase in price of energy. This would affect the derived demand for energy through two routes. First, assuming that the optimal production of utilized capital is held constant at T_0, the steeper iso-cost line R_2R_2' would alter optimal capital-energy combination in favour of capital (Figure 3.8). e_5 is the new point of optimality with reduced demand for energy from E_0 to E_5 and increased demand for capital from K_0 to K_5. This new point of optimality, which maintains the level of production of utilized capital, is achieved through an increase in the combined expenditure on capital and energy.[16]

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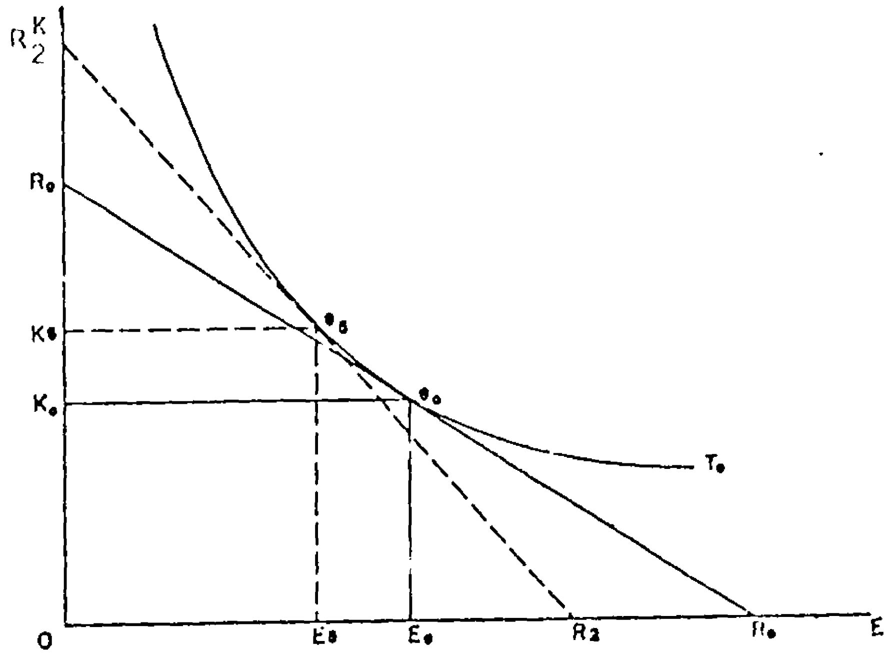
15. A close scrutiny of Figure 3.7 indicates that derived demand for energy increases ($E_0 < E_4$) as a result of an increase in price of capital, suggesting that the positive expansion affect ($E_4 - E_2$) is greater than the negative substitution effect ($E_0 - E_2$). The flatter the utilized capital isoquant, the greater the implied degree of substitutability between energy and capital. In theory, it should be possible for the two effects to cancel each other, in which case a change in price of capital would have no effect on the demand for energy.

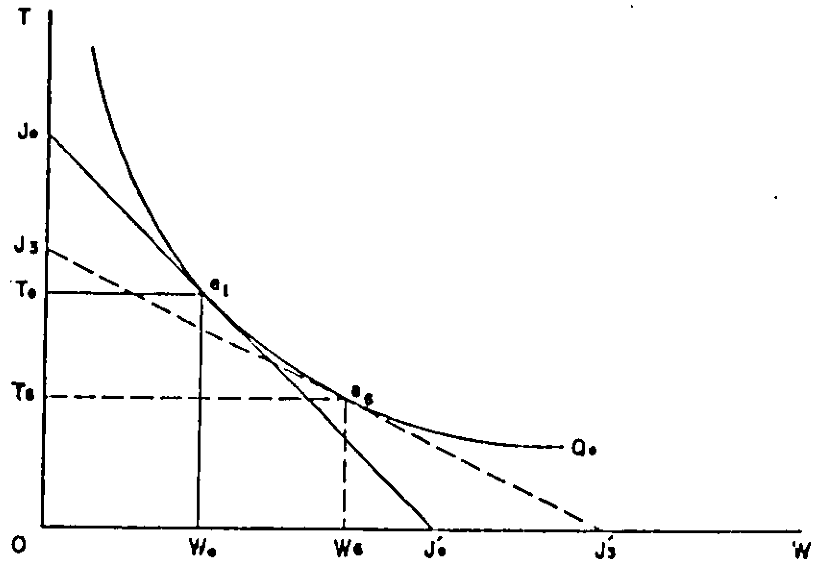
16. The implicit assumption here is that there exists sufficient budgetary flexibility to accommodate increased expenditure.

Figure 3.8 Capital energy adjustment following an increase in energy prices



Second, the initial increase in energy price increases the overall cost of utilized capital. This in turn makes the iso-cost curve for aggregate production less steep, altering the optimal utilized capital, labour-material combinations (Figure 3.9). J_3J_3' is the new aggregate iso-cost line under the new energy price regime, and e_6 is the new point of optimality showing reduced application of utilized capital ($T_6 < T_0$). The original level of aggregate economic activity can only be maintained with expansion in overall expenditure on inputs.

Figure 3.9 Adjustments in aggregate production following an increase in energy prices



To accommodate such contractionary effects on the demand for utilized capital, the utilized capital production map contracts, leading to reduced demand for both capital and energy (Figure 3.10). Production of utilized capital shrinks from T_0 to T_3 and given the prevailing price regime, e_7 becomes the new point of optimality with further reduction in demand for energy from E_4 to E_7.

Thus, a change in the price of energy has both a substitution effect, dictated by the actual relationship[17] between energy and capital in the production of utilized capital and represented by movement from e_0 to e_4 and an expansionary/contractionary effect dictated by the degree of dependence[18] of cost of utilized capital on the price of energy among other things.

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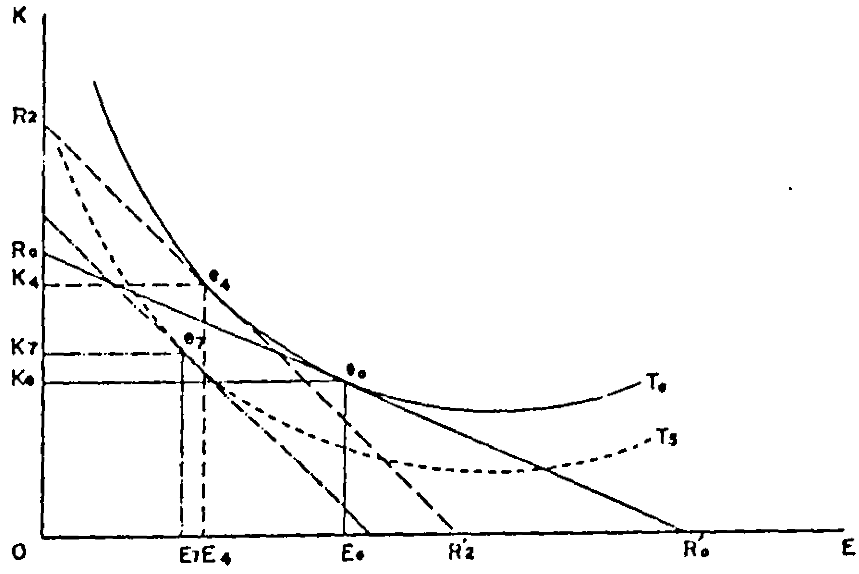
17. This relationship dictates the shape of the utilized capital's production isoquant.

18. Such degree of dependence determines the magnitude of change of slope of aggregate production iso-cost line and hence the change in the desired quantity of utilized capital.

Figure 3.10 Contractionary effects of a general increase in energy prices



The contractionary effect of an increase in energy price enhances the substitution effect to bring about a more significant reduction in the derived demand for energy. In other words, the demand for energy and its price are inversely related.

3.2.4 The Structure of the Economy

Any given utilized capital production map assumes the existence of a certain state of average energy-intensity in an economy. Such intensity changes with changes in the relative importance of different sectors in the economy, and in turn changes the general nature of the utilized capital production map. The implication is that for given levels of aggregate output, energy and equipment prices, changes in the structure of an economy create new equilibria in the utilized capital production map, leading to new levels of derived demand for energy. The actual impact of changes in structure of the economy depends on whether the change increases the overall dominance of the more or less energy intensive sectors of the economy.

In a similar way, changes in efficiency and /or conservation efforts, ceteris paribus, either induce movements along the utilized capital isoquant or downward shifts in the utilized capital production map. Either way, these movements reduce the gap between the theoretical minimum and the actual derived demand for energy, and hence reduce the energy intensity of the economy.

3.3 The Dynamics of Energy Demand

The process of adjustment to new points of equilibria can be exploited to anticipate the effect of a specified change in the conditions of demand on the overall demand for energy. In reality, such adjustments are induced by actual as well as expected changes in the conditions of demand. The process, however, takes place over time depending on whether the initial change in conditions of demand entail changes in rate of utilization of existing stock of energy-using equipment or changes in the stock itself.

Changes in utilization rate take time because energy users must adjust their use-habits in response to a change in the conditions of demand. The rate of adjustment of use-habits varies across groups of energy users. Generally, changes in the stock of energy-using equipment take longer than changes in the rate of utilization due to lock-in effects and lead times for replacing different types of energy-using equipment. This distinction between changes in the rate of utilization of capital stock and changes in the stock itself form the point of departure between the short-run, which is associated with the former, and the long-run which is associated with the latter, and constitute the dynamic dimension of energy demand.

3.4 Peculiarities Within the Energy Market in Kenya

So far, an attempt was made to develop a theory of demand for energy based on the assumption of existence of utilized capital production map that is characterized by a trade-off between capital and energy and constitutes the first stage in a two-stage optimization process. Consumers are assumed to maximize utility from purchase of goods and services while producers are assumed to minimize the costs of producing target levels of output, given specific price regimes or maximize production for given expenditure on inputs. Effective consumption and production are assumed to be preceded by the production of requisite quantities of utilized capital and decisions on how much of what form of energy are assumed to be secondary to decisions on optimal levels of economic activity, with its producer and consumer components; hence the notion of derived demand for energy.

Economic units are assumed to shift to new points of equilibria subsequent-upon a change in either one or more of the conditions of demand for energy. Such shifts were exploited to delineate the theoretical relationship between the demand for energy and a particular condition of demand. Of such conditions, the level of aggregate production, equipment and energy prices, the structure of the economy, efficiency and the state of energy conservation appear to be important on *apriori* theoretical grounds as suggested by section 3.2 of this Chapter.

However, there are some characteristics of the Kenyan economy that could interfere with the achievement of the suggested type of optimality, making the analysis of the impact of changing conditions of demand for energy more difficult. First, there are large public corporations and institutions for which cost-minimization may be secondary to other corporate objectives such as maximization of employment and sales. This could undermine the basis for producer optimality and raise possibilities of different kind of equilibria.

Second, the country imports most of its commercial energy under conditions that have tended to create foreign exchange problems. In this case, responses to changing conditions of energy demand are likely to be modified by budgetary inflexibilities. This, combined with the existence of oligopoly in the domestic oil industry, monopoly in the electricity sub-sector and administratively fixed commercial-energy prices which move in discrete jumps, portends continued disequilibria in the domestic energy markets.

Third, the structure of the Kenyan economy has been changing. In the energy sector, there have been quantum jumps in energy use and/or supply caused by sudden introduction of electric energy in regions of the country hitherto not electrified, and the commissioning of large energy-intensive industrial complexes. Such phenomena cannot be captured within the confines of a refined theoretical framework.

It was recognized that the combined effect of these peculiarities in the energy market in Kenya was significant. A search of the relevant literature, however, showed that the incorporation of such market peculiarities tends to be troublesome and appear to be best handled in studies that focus specifically on them (Bohi 1982: 2.40-2.42). For this reason, no attempt was made to incorporate them in this study. Nevertheless, it was recognized that the existence of fuel-price controls would lead to short-run price elasticities of demand which are smaller than otherwise. This was borne in mind in interpreting the empirical results of this study.

CHAPTER IV

METHODOLOGY

4.1 The Data

4.1.1 Data Types and Sources

The data used in this study were gleaned from official statistical publications including the Economic Survey, Statistical Abstract, Statistics of Energy and Power 1969-1978, Kenya Power and Lighting Company Limited's Annual Directors' Reports and Tariff booklets, and Ministry of Energy's summaries of the Petroleum Sector Data. Additional information was obtained from the Kenya Oil Refineries in Mombasa, Geothermal Power Station in Olkaria, Kenya Pipeline Company Limited headquarters in Nairobi and Portland Cement Factory in Mombasa.

From these sources, the following fuels were identified:[1,2]

- Motor spirit, used mainly for road transport and especially by private motorists, marketed in super/premium and regular grades. It is also used by the agricultural sector for water pumping.

- Gas oil or light diesel oil, used for road transport by large trucks, coaches and mini-buses. It is also used for railway transport, for water pumping and fueling

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1. See: World Bank (1982).

2. The term "fuel" is used here loosely to include electricity used by different consumers as defined by the Kenya Power and Lighting.

tractors in the agricultural sector, and for power generation.[3]

- Illuminating kerosene or paraffin, used mainly by the rural and low-income urban households mainly for cooking and lighting.

- Power kerosene, used by the industrial sector for fueling stationary equipment.

- Aviation spirit, used for fueling propeller-powered planes.

- Turbo fuel or jet fuel, used by jet planes.

- Heavy diesel oil, used as boiler fuel for stationary purposes and marine transport.

- Residual fuel oil, used for marine and railway transport, power generation, and for stationary industrial purposes.
- Liquid Petroleum Gas (LPG), used by the residential sector and institutions for cooking, lighting and water heating, and in glass manufacturing.

- Domestic electricity, used mainly for domestic purposes

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3. Use of gas oil for railway transport only began in 1978.

like cooking, lighting, water-heating, ironing and entertainments. It includes electricity use by small commercial and industrial concerns and institutions.

- Large industrial electricity, used in the industrial sector for fueling large industrial equipment. It also includes use by large commercial concerns.

- Off-peak electricity, used mainly for water pumping and heating.[4]

- Coal and coke (subsequently referred to as coal), initially used primarily for rail transport, but gradually for industrial purposes.[5]

From the various sources, annual countrywide sales of the various fuels were constructed for the period 1963 to 1985. However, the sales data showed that power kerosene was phased out of the Kenyan market after 1980, while sales of aviation spirit had been declining from 12,000 tonnes in 1963 to about 6,000 tonnes in 1986 due to the global phasing out of propeller type of aircraft engines which use it. Consequently, these two fuels were dropped from subsequent

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4. The Kenya Power and Lighting Company also includes street lighting and special contracts as a separate electricity consumer categories. However, sales to special contracts were discontinued after 1978 while sales for street lighting have stagnated around 10,000 kwhs since 1973. For these reasons, consumption of electricity by these categories of consumers was excluded from further analysis

5. Use of coal for rail transport was phased out altogether in the seventies.

analysis.

The same sources were used to extract annual data on other non-fuel variables for 1963-1985. These included population in Nairobi, private consumption, GDP, remunerations, manufacturing and repair output, agricultural output, transport, storage and communications output, service sectors' output,[6] total number of vehicles with current road licence, motor cars with current road licence, movements in main airports, estimated prices of petroleum products, number of large firms, revenue from sales of electricity to different categories of consumers and the price of charcoal.

4.1.2 Data Refinement

The data on specific fuels appeared in different units in the various publications and had to be expressed in some common unit. Initially, all petroleum fuels were expressed in litres while the electric fuels were expressed in kilowatt hours. An estimate of annual consumption of total commercial energy in tonnes of oil equivalent was obtained using conversion factors (Appendix G). This permitted the inclusion of total commercial energy in the list of fuels, making a total of twelve.

Using the extracted information on the number of households and firms in the country for each year, all sales of fuels used in industrial and commercial sectors were scaled down on the basis of the estimated number of large

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6. The service sector's output refers to monetary output from wholesale, retail, restaurants and hotels, finance, insurance and real estate.

firms while national sales of all other fuels were scaled down on the basis of the estimated number of households.[7] Included in the first category were sales of gas oil, heavy diesel oil, fuel oil, coal and industrial electricity. The rest of the fuels were included in the second category.

The current prices of all the petroleum fuels were directly available from the secondary sources, particularly from the Ministry of Energy's summaries of the Petroleum Sector Data. However, the price of coal was estimated from coal import data. Some prices of sales of electricity to different categories of consumers were available in the Kenya Power and Lighting Company's Tariff booklets. However, these were found to be inappropriate for our purposes because they were in schedules rather than single prices. In this respect, average prices of electricity sales to different consumer categories were estimated from sales data so as to permit the association of electricity consumption data to single average prices.[8]

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7. It was assumed that for those fuels which appear under both firms and households, at least one type of economic unit was more dominant than the other. For example, it was assumed that in the consumption of LPG, the household was more dominant than the firm and hence expressed LPG on per household basis. The purpose of this scaling was an attempt to relate fuel demand to the economic units that are capable of making independent decisions related to the use of a particular fuel.

8. For a fuller treatment of the conceptual problems associated with the use of different measures of electricity prices, See: Bohi (1982: 2.32-2.40).

All monetary values were converted into real 1976 terms,[9] and the annual data were converted to half-yearly data by applying exponential interpolation.[10] This increased the data base and enhanced the analytical flexibility.

4.1.3 Data Problems

This study used secondary time series data. There were problems associated with the use of recorded data because such data are usually gathered for general purposes and could not be expected to meet the specific requirements of a particular study. In the specific case of this study, existing data on petroleum products were restricted to national sales of specific products only. The breakdown of sales of petroleum products to specific sectors of the economy was not available for most of the years. Such a breakdown would have been useful.

Similarly, the secondary data on the sales of electricity exists in highly aggregated consumer categories which do not allow for the distinction of the unique characteristics of different types of users. It would, for example, be helpful for analytical and policy purposes to separate domestic from commercial electricity sales and

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9. Most of the monetary values expressed in current terms in the publications had their constant counterparts constructed on basis of different base years. To make the series constant, a certain amount of splicing was employed exploiting points of overlap in the original series. See: Intrilligator (1978: 68).

10. The assumption was that the growth rate for each variable between beginning and end of each year remained constant.

further distinguish between high income and low income domestic consumers.

Some variables that would have been useful in analysing the demand for energy such as the stock of different types of equipment and their prices could not be obtained from the existing secondary sources. In addition, this study could have benefitted from a longer time series than was constructable.

4.2 The Fuel Demand Models

The structure of energy demand varies across sectors and across fuels (Pindyck 1979). In addition, most fuels are not perfect substitutes and there are fundamental differences in individual fuels' market conditions. Further, different sectors reflect distinct energy-using groups which differ mainly with regard to the types of energy-using equipment, propensities to use energy, and end-use types.[11] One result of such a situation is that any analysis of energy demand based on aggregation across either fuels, sectors or both fuels and sectors is unlikely to elicit the correct behavioural responses.

In this study, fuel-wise demand models are proposed, the assumption being that in those cases where fuels are sector specific, the analysis at the fuel level leads to estimates that approximate sectoral fuel demand responses as well.[12] That aside, individual fuel demand models are

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11. See: Bohi (1982).

12. Data limitations could not permit analysis disaggregated at the sector level.

developed at two levels. The first level involves the construction of models for eliciting behavioural responses in terms of basic variables other than those representing either the structure of economy, efficiency or conservation. At the second level, two secondary models are proposed, one for capturing the impact of changes in the structure of the economy on the demand for individual fuels as well as for total commercial energy, and another for tracing any changes in efficiency of, and conservation in, energy use.[13]

4.2.1 Basic Fuel Demand Models

It is postulated that at any point in time, there would be some divergence between actual and desired demand for each fuel.[14] Suppose the desired demand for fuel i is given by:

4.1 $E_{it}^{*} = f(X_{it}, Y_t, Z_{jt})$

where E_{it}^{*} is per unit desired demand for fuel i at time t,[15] X_{it} is the price of fuel i, Y_t is per unit income,[16]

13. This two-level approach helps economize on degrees of freedom and creates room for sensible exploitation of the lag structure without appearing to stretch the concept too far. See also footnote 23.

14. This is because at any such point, markets would still be adjusting towards equilibrium. Such changes are not instantaneous since they involve changes in rate of equipment utilization, equipment retrofitting, as well as changes in their stock.

15. The unit here refers to the smallest economic unit capable of independent decisions related to the use of fuel i.

16. Several variants of income can be used as a measure of economic activity related to the use of a specific fuel.

and Z_{jt} is the price of a related fuel.[17] Economic theory does not appear to offer clear guidance on the precise functional form of this or any other general functional formulation.[18] That being the case, a multiplicative form of the general fuel demand function represented by equation 4.1 was chosen because: preliminary investigations based on the petroleum products data showed that such multiplicative form was superior to the additive model; it has received wider application than any other form in energy demand analysis (Bohi 1982); and has the advantage of yielding demand elasticities directly.[19]

The multiplicative form of equation 4.1 is:

$$4.2 \quad E_{it}^{*} = b_0^{*} X_{it}^{b1^{*}} Y_t^{b2^{*}} Z_{jt}^{b3^{*}} e^{\alpha_{it}}$$

where b_0^{*} is the usual constant, b_i^{*}, i = 1, 2, 3 are long-run price, income and cross elasticities of demand for fuel

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[17]. The price of capital was dropped as an explanatory variables because it was found impossible to estimate the average price of equipment related to specific fuels. Other explanatory variable considered important were added in the estimating equations of specific fuels.

[18]. In single variable analysis, a scatter diagram may give some indication as to whether or not the relationship is linear. This approach breaks down in the more popular multivariate analysis, is circular in logic, and shades little light on the precise nature of the functional form. See: Kelejian and Oates (1981).

[19]. However, the multiplicative form is consistent with optimization theory only where production functions are linearly homogeneous which requires that elasticities of substitution among inputs be equal and constant. It implies time-invariant elasticities and indispensability of all explanatory variables as a set. See: Christensen, Jorgensen and Lau (1973: 28-95) and Bohi (1982).

i,[20] and α_{it} is the error term with the usual stochastic assumptions.

Since the adjustment towards the desired levels of demand for fuel i following a change in the conditions of demand achieves only partial success in the course of any single period, the process of such adjustment can be summarized by:

$$4.3 \quad E_{it}/E_{it-1} = (E_{it}^{*}/E_{it-1})^{k}$$

where k is the coefficient of adjustment and 1-k is the proportion of adjustment achieved in the first period. If k approaches 1, most of the adjustment is achieved in the first period; hence the closer k is to unity, the faster the speed of adjustment.[21]

Combining 4.2 with 4.3 and taking natural logarithms[22] gives:

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20. b_j^{*}, $j = 1, 2, 3$ are long-run because they are associated with desired demand which is achieved only in the long-run.

21. This is the usual non-linear form of the flow adjustment model presented by equation 2.14 of Chapter II and is based on the assumption that the rate of utilization of all equipment that use fuel i is the same irrespective of vintage. For a detailed exposition of the coefficient of adjustment and relationship between short and long-term elasticities, see Intrilligator (1978), Pindyck and Rubinfeld (1976).

22. $E_{it}/E_{it-1} = (E_{it}^{*}/E_{it-1})^{k}$ implies that $E_{it} = (E_{it}^{*k})(E_{it-1}^{1-k})$. But $E_{it}^{*} = b_o^{*}X_{it}^{b1^{*}}\, Y_t^{b2^{*}}\, Z_{jt}^{b3^{*}}\, e^{\alpha_{it}^{*}}$. Therefore $E_{it} = (b_o^{*}X_{it}^{b1^{*}}\, Y_t^{b2^{*}}\, Z_{jt}^{b3^{*}}\, e^{\alpha_{it}^{*}})^{k}\, E_{it-1}^{1-k} = b_0^{*k}\, X_{it}^{kb1^{*}}\, Y^{kb2^{*}}\, Z_{jt}^{kb3^{*}}\, E_{it-1}^{1-k}\, e^{k\alpha_{it}^{*}}$ Taking natural logarithms of the expression for E_{it} gives $LnE_{it} = kLnb_0^{*} + kb_1^{*}LnX_{it} + kb_2^{*}LnY_t + kb_3^{*}LnZ_{jt} + (1-k)LnE_{it-1} + k\alpha_{it}$

$$4.4 \quad LnE_{it} = b_0 + b_1LnX_{it} + b_2LnY_t + b_3LnZ_{jt} + b_4LnE_{it-1} + U_{it}$$

where $b_0 = kLnb_0^*$, $b_1 = kb_1^*$, $b_2 = kb_2^*$, $b_3 = kb_3^*$, $b_4 = (1 - k)$ and $U_{it} = k\alpha_{it}^*$. Equation 4.4 lends itself to estimation since all its variables are observable. The estimation results directly yield b_i, $i = 1, 2, 3$ which are the relevant short-run elasticities plus an estimate for $1 - k$ which helps measure the speed of adjustment towards desired levels of demand. The long-run elasticities can subsequently be recovered from the short-run estimates using the implied coefficient of adjustment, i.e.

$$4.5 \quad b_j^* = b_j/(1-b_4) \text{ for } j = 1, 2, 3$$

This is because $1-b_4 = k$ and the short-run elasticities are given by:

$$b_j = kb_j^*$$

where b_j^*, $j = 1, 2, 3$ are the long-run elasticities related with the desired levels of demand for a particular fuel as shown in equation 4.2 and explained in the text.

Since X_{it}, Y_t and Z_{jt} represent the price of fuel i at time t, the incomes of the relevant economic units and the price of a related fuel, then b_1, b_2 and b_3 are the short-run own, income and cross elasticities of demand for fuel i, while b_0 is the usual constant, and b_0^*, b_1^*, b_2^* and b_3^* are their long-run counterparts.

Equation 4.4 is similar to that resulting from the application of Koyck type of lag structure, except for differences in the error term.[23] Implicit in the estimating equation arising from the two adjustment models is the assumption that the lag response to changes in all the included explanatory variables is the same. This assumption becomes far-fetched with additional explanatory variables.[24]

4.2.2 Secondary Fuel Demand Models

In an earlier section, it was suggested that changes in the structure of the economy may affect the demand for energy. There is need to separate the impact of economic-structure variables from that of other structural variables in order to assess the impact on energy demand of alternative sectoral growth strategies as well as relate energy demand to planned structural changes.

In this regard, additional log-linear demand functions in economic-structure variables are proposed for each fuel. These take the form:

$$4.6 \quad LnE_{it}' = h_0 + h_1 LnUP_t + h_2 LnA_t + h_3 LnM_t + h_4 LnT_t + h_5 LnS_t + u_t'$$

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23. The Koyck model generates error terms which are serially correlated with one another as well as with the lagged value of the dependent variable while the flow adjustment model generates less problematic error terms. See: Kelejian and Oates (1981: 157-160) and Pindyck and Rubinfeld (1976: 211-218).

24. There is, for example, no reason why the lag response to changes in fuel prices should be the same as that to changes in proportion of output accounted for by manufacturing. It is partly due to this consideration that a set of two functions was proposed for each fuel. See: Bohi (1982: 2-23).

where E_{it}' is demand for fuel i, A_t, M_t, T_t and S_t are shares of GDP accruing to agriculture, manufacturing and repair; transport, storage, refrigeration and communication, and the service sector, UP_t is urban population represented by the proportion of people living in Nairobi, h_0 is the usual constant, h_i, i = 1, 2, ... 5 are elasticities, and u_t' is an error term with the usual stochastic assumptions.[25]

A further set of secondary log-linear fuel demand models in fuel prices, incomes, and lagged consumption of the fuel in question is proposed, i.e.

$$4.7 \quad E_{it}'' = a_0 + a_1 LnX_{it} + a_2 LnY_t + a_3 LnE_{it-1}'' + u_{it}''$$

where a_0 is constant, a_i, i = 1, 2, 3 are structural coefficients, u_{it}'' is the error term, and all the other variables are as defined earlier.

The energy market conditions prevailing in Kenya seem to favour single-equation analysis of demand for fuels. This is because most fuel prices are fixed administratively and energy pricing policies are concerned with public

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25. The error term may arise because of misspecification of the model, application of imperfect functional forms, incorrectly measured variables and basic randomness in the behaviour of energy using units. In the single equation models of fuel demand, the appropriate stochastic assumptions are that the error terms are random variables normally distributed with zero means and constant variables, and are unrelated with either the explanatory variables or among themselves. See: Intrilligator (1978).

interest.[26] As a result, fuel prices are predetermined, and the energy markets operate through quantity adjustments rather than price variations. The implication is that simultaneous equation bias and identification problems are not important (Uri 1980) and were therefore assumed away (Uri 1980: 197-216).

4.3 Techniques of Analysis

The data were applied on the three log-linear models proposed for each fuel and summarized by equations 4.4, 4.6 and 4.7 presented in the previous section of this Chapter, using the Ordinary Least Squares (OLS) methods of estimation. This was done with the help of the MINITAB statistical computer package developed by the University of Pennsylvania and available in the University of Surrey where the initial analysis of the data was done, and the LOTUS II package available in the Ministry of Energy where the final analysis was done.

The basic idea behind the OLS method of estimation is to choose values of the structural coefficients of any functional relationship that minimize the error sum of squares.[27] Since the error terms built into each of the models are not observable, it was assumed that:

a) the error terms are normally distributed with zero mean and constant variance

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26. It is mainly for this reason that prices are regulated in the first place.

27. For details on the OLS method of estimation, see Intrilligator (1978: 91-98).

b) the explanatory variable are non-stochastic and error free

c) the number of observations on all the explanatory variables exceed the number of structural parameters to be estimated

d) there is no exact linear relationship between any of the explanatory variables.

The estimations yielded estimates of all the requisite short-run elasticities of demand and coefficients of adjustment for the basic fuel demand functions exemplified by equation 4.4, as well as estimates of the elasticities of the economic-structure variables for each of the fuels as presented in equation 4.6. Subsequently, estimates of the implied long-run elasticities of demand for the fuels were obtained by exploiting the relationship between such long-run elasticities, their short-run counterparts, and the estimated coefficients of adjustment as shown in equation 4.5 above.

In addition, trends in the constant terms and coefficient of adjustment for the period 1963-1985 were analysed by sequentially applying OLS on the simple log-linear fuel demands functions using 15 half-yearly moving data blocks. This process generated 28 estimated equations for each of the fuels, from which 28 estimated values of the constant terms and coefficients of adjustment were extracted and plotted on graphs for ease of appreciating their trends. The basic premise here was that a declining constant term shows downward shifts in the fuel demand schedules associated with autonomous trends towards energy conservation, and vice versa. Similarly, increasing values of the coefficient of adjustment would be a manifestation of faster speeds of adjustment of energy demand toward desired levels, which in turn implies improvements in the efficiency with which energy is used and vice versa.[26]

4.4 The Expected Signs of Estimated Parameters

The estimation of the basic fuel demand functions was expected to yield four parameters for each fuel, namely, short-run own price elasticities of demand, short-run income elasticities of demand, coefficients of adjustment, and a short-run cross elasticities of demand. In conformity with economic theory, it was expected that the estimation procedure would yield negative short-run price elasticities of demand, positive short-run income elasticities of demand, positive coefficients of adjustment, and negative cross elasticities of demand. In addition, the hypothesized relationships between the short-run and the long-run coefficients represented by equation 4.5 guarantees that the signs of the latter would be the same as those of the former.

There was no firm theoretical guidance on the exact nature of the relationships between the demand for commercial fuels and variables used to describe the structure of the economy. However, it was expected that increases in the proportion of people living in Nairobi

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26. These interpretations are true only to the extent that the fuel demand functions employed for this purpose maintain the same "character" throughout the entire time span under consideration (Uri 1980: 197-216).

would, ceteris paribus, lead to an increase in the demand for the two automotive fuels, LPG, domestic electricity and possibly off-peak electricity. For this reason, the elasticities of demand for these fuels with respect to the proportion of people living in Nairobi were expected to be positive. In addition, there was the possibility that the demand for the industrial fuels such as heavy diesel oil, fuel oil, coal and industrial electricity would be positively related with the proportion of people living in Nairobi. This was because most industries which use such fuels are based in the urban areas especially in Nairobi.[29]

The elasticity of demand for illuminating kerosene with respect to the proportion of people living in Nairobi was expected to depend on the socio-economic status of the average immigrant/arrival. If most immigrants/arrivals belong to the lower income bracket, an increase in their proportion would lead to an increase in the demand for illuminating kerosene, and vice versa. However, the actual sign of the relationship and hence of the estimated elasticity could not be determined apriori. Overall, the elasticity of demand for total commercial energy with respect to the proportion of people living in Nairobi was expected to be positive.

Increases in the proportion of GDP accruing to agriculture were expected to exert a positive impact on the demand for gas oil, which is used for the transporting agricultural produce and ploughing, in addition to other

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29. This also depends on the appropriateness of the proportion of people living in Nairobi as a measure of the extent of urbanization.

uses; and the demand for off-peak electricity used for water pumping for irrigation, among other uses. The impact on the demand for all the other fuels was not discernable apriori However, the elasticity of demand for total commercial energy with respect to changes in the proportion of GDP accruing to agriculture was expected to be negative. In other words an increase in the proportion of GDP accruing to agriculture which would imply a reduction in the proportion of GDP accruing to other more commercial-energy-intensive sectors, would lead to a decline in the overall demand for commercial energy.

Changes in the proportion of GDP accruing to manufacturing were expected to have positive effects on the demand for the industrial fuels including LPG, heavy diesel oil, fuel oil, coal and industrial electricity; as well as on total commercial energy. The effect of such changes on the demand for all the other fuels could not be discerned apriori. On the other hand, changes in the proportion of GDP accruing to the transport sector were expected to have a positive effect on the demand for motor spirit, gas oil and total commercial energy. However, the effect on the demand for all the other fuels could not be determined apriori.

Finally, changes in the proportion of GDP accruing to the service sector were expected to have positive effects on the demand for LPG and residential electricity only,[30] but their effects on the demand for the other fuels could not be anticipated apriori.

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30. Residential electricity includes consumption by commercial consumers in the service sector.

4.5 Possible Statistical Problems:

The application of time series data on the proposed models pre-disposed the estimations to autocorrelation due primarily to the time factor. This was especially so because of the creation of half-yearly data from annual data using non-linear interpolation. In addition, the inclusion of lagged-values of the dependent variables on the explanatory side of the models was expected to introduce/accentuate collinearity among the explanatory variables. There were, however, no apriori grounds for expecting these problems to be serious enough to warrant any corrective measures[31].

31. Serious cases of autocorrelation and/or multicollinearity introduce conceptual biases which lead to very small t- ratios. This was not found to be the case in this study. See also foot-note 26 in chapter v.

CHAPTER V

EMPIRICAL RESULTS

5.1 Estimation Results

The OLS estimation results for equation 4.4 and 4.6 of Chapter IV are presented in Tables 5.1 and 5.2 respectively. In addition, trends in the estimated values of the constant terms and the coefficients of adjustment obtained from sequential application of equation 4.7 on each of the twelve fuels are shown in Figures 5.1 to 5.12. Table 5.1 shows a wide range of price and income elasticities of demand for fuels, both short term and long term, and a wide range of coefficients of adjustment. Similarly, Table 5.2 shows a wide range of elasticities of demand for fuels with respect to changes in proportion of total output accruing to different sectors of the economy. The graphs show varying trends of the constant terms and coefficients of adjustment associated with the demand for different fuels.

5.1.1 Basic Fuel Demand Functions

The estimated short-run price elasticities of demand for fuels range from -.161 for domestic electricity to -1.05 for coal, with an unweighted average of -.330.[1] The long-run price elasticities range from -.527 for LPG to -3.00 for

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[1]. This average excludes the estimated price elasticities of demand for jet fuel, heavy diesel oil, fuel oil and industrial electricity which are not significantly different from zero.

off-peak electricity, with an unweighted average of -1.357.[2] Excluding the high short-run price elasticity of demand for coal and the high long-run price elasticity of demand for off-peak electricity, the average short-run and long-run price elasticities of demand for the fuels become -.211 and -1.03 respectively.

The results indicate that in the short-run, the demand for coal is most price-responsive while that for industrial electricity is least price-responsive. The demand for motor spirit, gas oil, and off-peak electricity responds averagely to price changes in the short-run. The demand for illuminating kerosene, LPG, and domestic electricity respond in a less-than-average way to changes in their prices in the short-run. However, the demands for jet fuel, heavy diesel fuel, fuel oil and industrial electricity do not respond to changes in their prices in the short-run.

Generally, the demand for fuels in Kenya is price inelastic in the short-run. This implies that either fuel use in the country is a matter of necessity or that inter-fuel substitution possibilities are limited in the short-run, or both. This latter possibility is especially likely with the two automotive fuels and the residential fuels. Price inelasticity could also arise where fuel costs account for a small part of total operating costs. This is true of jet fuel, and accounts for the differences in the estimated short-run price elasticities of demand for motor spirit used

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2. This average excludes jet fuel, heavy diesel oil, fuel oil, domestic electricity and industrial electricity whose long-run price elasticities could not be estimated because their short-run counterparts were not significantly different from zero.

by motor cars, and gas oil used for large trucks and coaches. While the costs of motor spirit and gas oil contribute to total operating costs, motor spirit's contribution is more significant than gas oil's in their appropriate transport operations. On this account, motor spirit is likely to be more price elastic than gas oil.[3]

More significantly, low price elasticities of demand for fuels may result from market distortions caused by administrative controls on fuel prices. The exception to this is coal, which is not subject to any price controls, and whose demand analysis returned the highest price elasticity of demand.

The possibilities for inter-fuel substitution are limited in the short-run. This is possibly because most of the fuel-using equipment tends to be fuel specific, and any change in the type of fuel would generally require an accompanying change of equipment, which is more likely only in the long-run. In some cases, some alternative fuels are used along with others. However, such alternative fuels are for contingency use, and cannot be considered as strictly substitutes. This is the case in the residential sector where equipment manufacturers have already recognized the need for contingency arrangements and are producing bi-fuel appliances. In such cases, households enjoy fuel flexibility, but maintain some preferred fuel, used

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3. The actual difference between the estimated price elasticities of demand for motor spirit and gas oil were not statistically significant..

regularly, while the other is used when the need arises.[4]

The estimated long-run price elasticities of demand are larger than their short-run counterparts for all fuels. This is because economic units are better able to exercise their discretion in fuel and equipment choice in the long-run. In this regard, the large long-run price elasticity of demand for off-peak electricity reflects the many fuels available for water heating, the main activity in which off-peak electricity is applied. Such choices include LPG, off-peak electricity, residential electricity, charcoal and more recently, solar energy.

The results show positive short-run income elasticities of demand for all fuels except jet fuel and illuminating kerosene. On this account, illuminating kerosene appears an inferior fuel, to be given-up in preference to other fuels when incomes permit. However, this is likely to be so in the urban residential sector only where alternative fuels, especially electricity and LPG, are available. In the rural areas, fuel choices are generally limited even with increased incomes. A negative income elasticity of demand for jet fuel on the other hand implies that it is incomes of international travellers, rather than those of Kenyans, which influence the demand for international travel and

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4. This particular development has so far affected cookers which underscores the fact that most residential energy use in associated with cooking. There are presently cookers that use both electricity and LPG. If the preferred fuel is electricity the LPG mechanism is switched-to only when electricity is not available such as during a blackout. If on the other hand LPG is the preferred fuel, electricity is used only when LPG is not available such as during a general shortage or when shopping for new supplies.

hence the derived demand for jet fuel.[5]

The values of the positive short-run income elasticities of demand for the fuels range from .259 for motor spirit to .863 for gas oil, with an unweighted average of about .506.[6] The estimated short-run income elasticity of demand for total commercial energy is low.[7] These elasticities show that motor spirit, gas oil, LPG, fuel oil, coal, off-peak, industrial electricity and residential electricity are normal goods. However, all the short-run income elasticities are less than unity, implying that a 100% increase in incomes leads to a less than 100% increase in the demand for the fuels. In this sense, the short-run demand for the fuels is income inelastic.

The implied long-run income elasticities are larger than the short-run counterparts, and range from .899 for fuel oil to 5.83 for gas oil with an unweighted average of about 2.275.[8] Excluding the high long-run income elasticity of demand for gas oil, the unweighted average income elasticity is 1.683. This means that a 100% increase in incomes would, *ceteris paribus*, lead to more than 160%

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5. The estimated income elasticity of demand for jet fuel is in any case not significantly different from zero, implying that the demand from jet fuel is insensitive to changes in incomes in Kenya.

6. The average excludes the income elasticities for heavy diesel oil and domestic electricity which are not significantly different from zero.

7. The poor performance of the total commercial energy equation is largely due to aggregation problems.

8. This average excludes the negative income elasticities for jet fuel and illuminating kerosene as well as those for heavy diesel oil and domestic electricity whose short-run counter parts were not significantly different from zero.

increase in demand for the fuels on average. In this sense, the demand for fuels is income-elastic in the long-run. In other words, the demand for commercial energy grows by a factor greater than the rate of economic growth in the long-run.

The results show that charcoal is substitutable for both illuminating kerosene and domestic electricity, with short-run cross elasticities equal to .141 and .041 respectively. This is expected since both illuminating kerosene and domestic electricity are used by the residential sector for cooking, the main activity in which charcoal is used. It is noted, however, that charcoal-using appliances are cheaper than either kerosene or electric appliances, dampening the relevant substitution possibilities. In the industrial sector, some substitution possibilities exist between industrial electricity and both fuel oil and coal, with cross elasticities of .104 and .78 respectively. That aside, all the estimated positive cross elasticities of demand are small, albeit significant, except between industrial electricity and coal, with an unweighted average of about .10.[9] This means that short-run inter-fuel substitution possibilities are limited.

The cross elasticity of demand between LPG and domestic electricity is -.185 and is significantly different from zero. This implies that a 100% increase in the price of LPG would lead to 18.5% decrease in the demand for residential electricity. However, it seems unlikely that LPG and

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9. This excludes the inexplicably large cross elasticity of demand between industrial electricity and coal.

residential electricity could be complements.

The results further show a wide range of elasticities of demand for fuels with respect to their lagged-consumption. The demand for coal appears least responsive while jet fuel shows greatest responsiveness to lagged-consumption. Further analysis shows that the unweighted average elasticity of demand for fuels with respect to their lagged values is about .742, while that for total commercial energy is .94.[10] These coefficients show the different speeds with which economic units adjust their demand for specific fuels towards equilibrium levels following a change in the conditions of demand such as own prices, prices of other fuels, and incomes. The coefficients imply that it takes an average of about 1 year and 2 months to achieve half of the necessary adjustment towards equilibrium levels of fuel demand.[11]

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10. This average excludes the estimated elasticity of demand for residential electricity with respect to its lagged consumption because it overshot the theoretical limit of unity.

11. This is called the medium or mean lag which has been shown to be equal to $k/(1-k)$ and is estimated by $Ln(.5)/Ln(1-k)$ (Johnston 1972: 299; Pindyck 1979).

5.1.2 The Impact of Changes in the Structure of the Economy On the Demand for Fuels

The impact of changes in the structure of the economy on individual fuels is shown in Table 5.2. The proportion of total population living in Nairobi shows a positive effect on all fuels except illuminating kerosene and heavy diesel oil. The demand for domestic electricity and jet fuel show a particularly high urbanization elasticity of demand.[12] In other words, an increase in urbanization, ceteris paribus, increases the demand for most fuels in general, while the demand for domestic electricity and jet fuel grows at faster rates than the rate of increase in the level of urbanization. The results reflect the fact that domestic electricity is primarily an urban fuel. Illuminating kerosene is, on the other hand, used in the rural as well as urban areas. However, its use is much more widespread in the former, hence the inverse effect of urbanization on its demand.

The negative urbanization elasticity of demand for heavy diesel oil is significantly different from zero, implying that urbanization inversely affects the demand for heavy diesel oil. A positive elasticity would have been more reasonable because heavy diesel oil is essentially an industrial fuel and the majority of industries are concentrated in urban areas. In addition, the results show a negative urbanization elasticity of demand for off-peak electricity, reflecting its use in water pumping for agriculture which is a rural activity.

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12. The proportion of people living in Nairobi is used as a proxy for urbanization.

The demand for most fuels responds positively to changes in the proportion of total output accruing to the manufacturing and repair sector.[13] The estimated elasticities range from .391 for fuel oil to 1.934 for jet fuel, with an unweighted average of 1.19.[14] In other words, a 100% increase in the proportion of output accruing to manufacturing and repair increases the demand for all fuels on average by about 119%, and the demand for heavy diesel oil and jet fuel by almost 200%.

Further, the results show that the effect of changes in the proportion of output accruing to agriculture varies from fuel to fuel. Most of the positive elasticities are low except for industrial electricity, which is greater than unity. That notwithstanding, the results suggest that an increase in the proportion of output accruing to agriculture would increase the demand for motor spirit, gas oil, kerosene, fuel oil and domestic and industrial electricity, but generally by a factor less than the initial increase in the sector's contribution to total output. The increase in agricultural sector's contribution would, however, reduce the demand for jet fuel, LPG, coal, heavy diesel oil, and off-peak electricity, which are either industrial or urban fuels.

Low positive agricultural sector's elasticities and high manufacturing and repair sector's elasticities of

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13. The large negative manufacturing elasticity of demand for coal is inexplicable.

14. The negative and non-significant elasticities of demand for fuels with respect to proportion of output accruing to manufacturing and repair are excluded from this calculation.

demand for fuels reflect the relative commercial energy intensities of the two main sectors in the economy, with manufacturing and repair being a more commercial energy-intensive sector than agriculture.

The proportion of total monetary output accruing to transport, storage and communications show positive impact on the two automotive fuels, on fuel oil, and on domestic and industrial electricity. However, its impact on jet fuel, LPG and off-peak electricity is negative.[15] The overall elasticity of demand for total commercial energy with respect to proportion of output accruing to the transport, storage and communications sector is negative, suggesting that on balance, the demand for total commercial energy falls as the dominance of the sector increases, *ceteris paribus*. This is possible only to the extent that the increased dominance of the sector reflects increased dominance of the storage and communications sub-sectors relative to the more energy intensive transport sub-sector.[16] The negative elasticity here is otherwise difficult to explain.

The service sector's contribution to total output shows positive impacts on LPG, domestic and industrial electricity, and coal; and negative impact on all other fuels. The elasticities for the two automotive fuels and fuel oil are not significantly different from zero. The service sector consists of wholesale and retail trade,

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15. Those for coal, kerosene and heavy diesel are not significantly different from zero.

16. Data on this sector is composite and does not show the relative contribution of the three sub-sectors.

insurance, and real estate sub-sectors which use mainly electricity and LPG. This is what the results seem to underline, especially because domestic and industrial electricity are defined in a way that includes commercial consumption.[17]

5.1.3 Conservation Trends

The graphs show increasing trends for the constant terms associated with the demand for motor spirit, jet fuel, illuminating kerosene, LPG, heavy diesel oil and off-peak electricity. The trends of the constant terms associated with the demand for other fuels are not unidirectional. For example, the constant term associated with the demand for gas oil shows a declining trend from the 1st to the 13th session, and increases thereafter.[18] Those for fuel oil and industrial electricity show a similar pattern. However, the constant terms associated with the demand for residential electricity and coal show a gradually declining trend.

Declining constant terms suggest autonomous decreases in the demand for fuels associated with fuel conservation among other things,[19] and vice versa. The results,

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[17]. The overall service sector's elasticity of demand for total commercial fuel is however positive albeit small.

[18]. These constant terms are estimated from sequential application of moving blocks of 15 half yearly data on equations 4.7 of Chapter IV. These sessions run from 1st half of 1963 to 1st half of 1970, 2nd half of 1963 to 2nd half of 1970, 1st half of 1971 and so on.

[19]. The assumption is made that the conditions of demand have remained much the same over the entire time period. A change in the conditions of demand such as increased importance of some of variables not included in the specifications could bring about changes in the constant term totally unrelated with conservation.

therefore, imply that energy users in Kenya have been making firm conservation measures with respect to their use of coal and residential electricity. For other fuels, there appears to have been attempts to conserve when condition of demand dictated it, with lapses as soon as such conditions become more favourable.[20] For yet other fuels, there is no evidence of conservation.

5.1.4 Changes in the Efficiency of Fuel Use

The graphs also show that the coefficients of adjustment associated with the demand for LPG, coal and off-peak electricity remained unchanged between 1963 and 1985, those associated with the demand for illuminating kerosene, heavy diesel oil, fuel oil, residential electricity and industrial electricity show a gradually increasing trend, while those associated with the demand for motor spirit, gas oil and jet fuel show changing but undiscernible trends.

A gradually increasing coefficient of lagged dependent variable shows, other things being equal, an increase in the speed with which the demand for fuels adjust to equilibrium levels, and hence improvements in the efficiency with which fuels are used. The converse is also true.[21] In that case,

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20. A certain amount of reversible conservation such as reduction in unnecessary travelling is likely to have accompanied the oil price shocks of 1973-1974 and 1979-1981.

21. Recall from Chapter IV that coefficient of the lagged dependent variable used as an explanatory variable equals (1-k) where k is the coefficient of adjustment. When the value of the coefficient of the lagged dependent variable approaches unity, then this means a faster rate of adjustment towards desired level of demand for a particular fuel, which in turn would mean a faster rate of replacement of old energy using-equipment in favour of newer, more efficient equipment. See: (Uri 1980: 3).

the results show that whereas there has been steady and/or eventual improvements in the efficiency with which illuminating kerosene, domestic electricity, heavy diesel oil, and industrial electricity are used, the efficiency in the use of automotive and jet fuels appear erratic. That for coal remained consistently low, while that for the consumption of LPG remained consistently high throughout 1963-1985.

5.2 Evaluation of Demand Models

Demand theory prompts us to expect negative relationships between the demand for individual fuels and their prices. The results uphold this expectation for all fuels. For some of the fuels however, the estimated price elasticities are small, and some are not significantly different from zero. In such cases, it is contended that either recorded price variations have not been sufficient enough to have a significant impact on the demand for the respective fuels, or the market distortions brought about by administratively determined prices destroy any meaningful relationship between the demand for the fuels and their prices.

The estimation results also showed positive income elasticities of demand for most of the fuels. This is in complete conformity with theoretical expectations except in cases where there are possibilities of the fuel being an inferior good. This was found to be true of illuminating kerosene.[22]

The coefficients of the lagged dependent variables included in the fuel-demand function should assume values between 0 and Unity by design.[23] The results upheld this condition for all the fuels except domestic electricity. While the results for domestic electricity are inexplicable, the results for the coefficient of the lagged-dependent variable are generally commendable, especially because the estimation were unrestricted.

All the estimated basic fuels demand models show high explanatory powers. For seven of the fuels the included variables explained at least 95% of the variations in the demand for the respective fuels. The included variables as a group explain at least 75% of the variations in the demand for each of the fuels.[24] For all the fuels, the calculated F values are invariably greater than the critical values at the 1% level of significance. This implies that the estimated fuel demand models are statistically significant at that level. This in turn suggests that the fuel demand models do explain the phenomena under investigation.

The majority of the t- ratios for the short-run price and income elasticities and coefficient of the lagged-dependent variables are greater than 2 in absolute terms. The implication is that the majority of such elasticities

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22. This conforms with results obtained by other. See for example results on Cody's work referred to in World Bank (1981b: 84).

23. This is because such coefficients are defined as $(1-k_i)$ for fuel i where $0 < k_i < 1$.

24. The figures are interpretations of the estimated R^2 shown in Table 5.1.

and coefficients are significantly different from zero, and that the variables associated with them do influence the demand for the relevant fuels. The t- ratios associated with the estimated cross elasticities indicate that these elasticities are also significantly different from zero at least at the 5% level of significance, the exception being the cross elasticity of demand between heavy diesel oil and industrial electricity.[25]

The economic-structure models performed well on their own, explaining 89% of the variations in the demand for the fuels on average. However, the model for illuminating kerosene performed worst in this respect, with the economic-structure variables explaining only 63% of the variations in its demand. Most of the t-ratios are high, showing that most of the estimated coefficients of the economic-structure variables are significantly different from zero. The estimated F values are also high, implying that the fuel demand models based on the economic-structure variables are significant in general.

The relevant statistics showed the presence of some autocorrelation in the estimated fuel demand equation, as well as some multicollinearity between some of the explanatory variables.[25] The overall results, however, showed that such statistical problems were not serious.[26] The estimated fuel demand equations are, therefore, sound on broad theoretical and statistical criteria, and form a basis for formulating fuel demand managemer policies.

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25. The presence of lagged fuel consumption on the explanatory side made the D W statistic powerless. The h-statistic and simple correlation coefficients were used to test for autocorrelation and multicollinearity respectively.

26. The t-ratios are higher than they would have been with a serious case of autocorrelation and/or multicollinearity.

5.3 Testing of Hypotheses

A number of hypotheses were postulated. First, it was hypothesized that the demand for individual fuels in Kenya is influenced by fuel prices, income and the structure of the economy. The results showed non-zero price and income elasticities for most of the fuels with the estimated basic fuel demand models in prices, incomes and lagged dependent variables yielding high explanatory powers. The estimated fuel demand models in economic-structure variables also showed high explanatory powers.

Fuel prices, income-levels and the structure of the economy have a definite impact on the demand for most fuels, and explain most of the variations in such demand. It is not possible to explain commercial energy demand in Kenya without taking these variables into direct consideration. On that account, we accept the first hypothesis in its entirety.

Second, it was hypothesized that the demand for most fuels show lower price relative to income elasticities of demand, and exhibit poor substitution possibilities. The results showed that while the short-run elasticities are generally low, the price elasticities are lower than their income counterparts except for coal, residential and off-peak electricity. This distinction is maintained in the long-run, although all the elasticities are larger than they are in the short-run[27]. The estimations also elicited cross elasticities of demand for

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27 It was not possible to test for the significant between the long term elasticities because the estimation procedures did not generate the necessary long-term test statistics.

most of the fuels for which such an elasticity was estimatable, the demand for coal being the only exception.

Low price and cross elasticities of demand suggest limited substitution possibilities. However, any degree of substitution, however small, suggests that while total energy may be a basic necessity, this is hardly the case for individual fuels. That aside, the second hypothesis, is partly accepted. In addition, it is noted that the substitution possibilities vary from fuel to fuel.

The analysis showed consistent trends towards conservation in the use of coal anddomestic electricity only, and consistently high and/or improvements in the efficiency with which illuminating kerosene, domestic electricity, heavy diesel oil, industrial electricity and LPG are used evidenced. There are, however, no general trends for all fuels with respect to either conservation or efficiency of commercial energy use. On this account, there is no sufficient ground for accepting either the third hypothesis which states that the efficiencies with which commercial fuels are used have not improved over the years, or the fourth hypothesis which states that there has been a general tendency towards energy conservation.

Table 5.1 Basic fuel demand elasticities

Fuel	Short-term elasticities[1]				Long-term elasticities					
	Price	Income	Lagged-dependent	Other	Price	Income	R^2	df	D-W	F estimated[2]
Motor spirit	-.233	.259	.743	.426[3]	-.907	1.008	.90	38	2.75	119
	(-3.55)	(2.15)	(4.83)	(2.61)						
Gas oil	-.206	.863	.852	-	-1.392	5.83	.98	39	1.001	588
	(-4.19)	9.605)	(7.816)							
Jet fuel	-.053	-.490	.92	-	-	-	.83	39	2.53	70
	(-.65)	(-.63)	(6.03)							
Illuminating kerosene	-.126	-.227	.770	.141[4]	-.548	-	.86	37	1.314	68
	(2.221)	(-1.523)	10.423)	(2.714)						
LPG	-.147	.756	.721	-.185[5]	-.527	2.71	.80	29	.872	33
	(-1.592)	(2.311)	(5.885)	(-2.25)						
Heavy diesel oil	-.048	.065	.804	-	-	-	.95	37	1.205	176
	(-.107)	(.058)	(5.759)							
Fuel oil	-.131	.443	.505	.1044[6]	-	.899	.78	38	2.17	39
	(1.01)	(2.34)	(2.52)	(1.75)						
Coal	-1.05	.547	.405	.78	-1.765	.919	.75	37	2.2918	31
	(6.4061)	(2.376)	(4.270)	(4.515)[6]						
Domestic electricity	-.161	.028	1.148	.041[4]	-	-	.98	37	.9797	453
	(-2.124)	(.110)	(9.320)	(1.806)						
Off-peak electricity	-.39	.352	.87	-	-3.00	2.708	.95	38	1.356	269
	(-5.122)	(2.43)	(19.772)							
Industrial Electricity	-.030	.319	.828	-	-	1.85	.98	38	1.105	621
	(-.757)	(2.058)	(6.757)							
Total commercial energy	-	0.054	.94	-	-	.90	.98	39	1.0607	1650
		(1.584)	(18.048)							

Notes: 1. Figures in brackets are t-ratios
2. Estimated using the formular $F = (R^2/k-1)/(1-R^2)/(n-k)$
3. Vehicles with current road licence
4. Price of charcoal
5. Price of residential electricity
6. Price of industrial electricity

Table 5.2 Elasticities of economic-structure variables

Fuel	Urbani-zation	% of monetary output accruing to: Agric-ulture	Manu-fact.	Trans-port	Services	R^2	df	D-W	F Estimated
Motor spirit	.690 (2.934)	.114 (1.163)	.989 (4.399)	.921 (10.738)	-.206 (-1.081)	.93	36	.917	113
Gasoil	.875 (2.135)	.0226 (.177)	.925 (4.023)	.712 (3.50)	-.100 (-.420)	.97	36	.616	233
Jet Fuel	1.604 (5.734)	-.247 (-1.347)	1.934 (4.053)	-1.356 (-6.416)	-1.546 (5.564)	0.93	37	.628	144.9
Illuminating kerosene	-.214 (-.579)	.341 (2.791)	1.403 (4.42)	-.17 (-1.13)	-.592 (-2.187)	.58	36	.906	12
LPG	.192 (.268)	-.571 (-2.133)	-.055 (-.117)	-1.531 (-3.581)	.980 (2.155)	.52	23	.099	8.3
Heavy diesel oil	-1.224 (-3.108)	-.628 (-2.430)	1.88 (2.801)	-.358 (-1.20)	-2.598 (-6.641)	.86	36	.858	52
Fuel oil	-	.648 (3.171)	.391 (.979)	.740 (4.481)	-.201 (-.576)	.92	37	.802	123
Coal	-.454 (-.386)	-1.209 (-1.568)	-3.933 (-1.962)	.655 (.739)	1.818 (1.558)	.344	37	1.138	6.4
Domestic electricity	1.584 (3.421)	.548 (5.096)	.807 (1.022)	.925 (2.643)	2.297 (4.995)	.81	36	.7944	35
Industrial electricity	.34 (1.756)	1.673 (8.587)	.671 (5.255)	.65 (1.95)	.231 (1.568)	.94	36	.859	137
Off-peak	-.784 (-3.80)	-.725 (-5.36)	.560 (1.542)	-1.051 (-6.742)	-1.180 (-5.761)	.73	37	.860	29.3
Total commercial energy	.846 (8.033)	.161 (2.331)	.376 (2.093)	-.586 (-7.362)	.29 (2.768)	.98	36	.727	353

Note: Figures in brackets are t-ratios.

Figure 5.1: Trends in the constant term and the Coefficient of lagged dependent variable associated with the demand for:

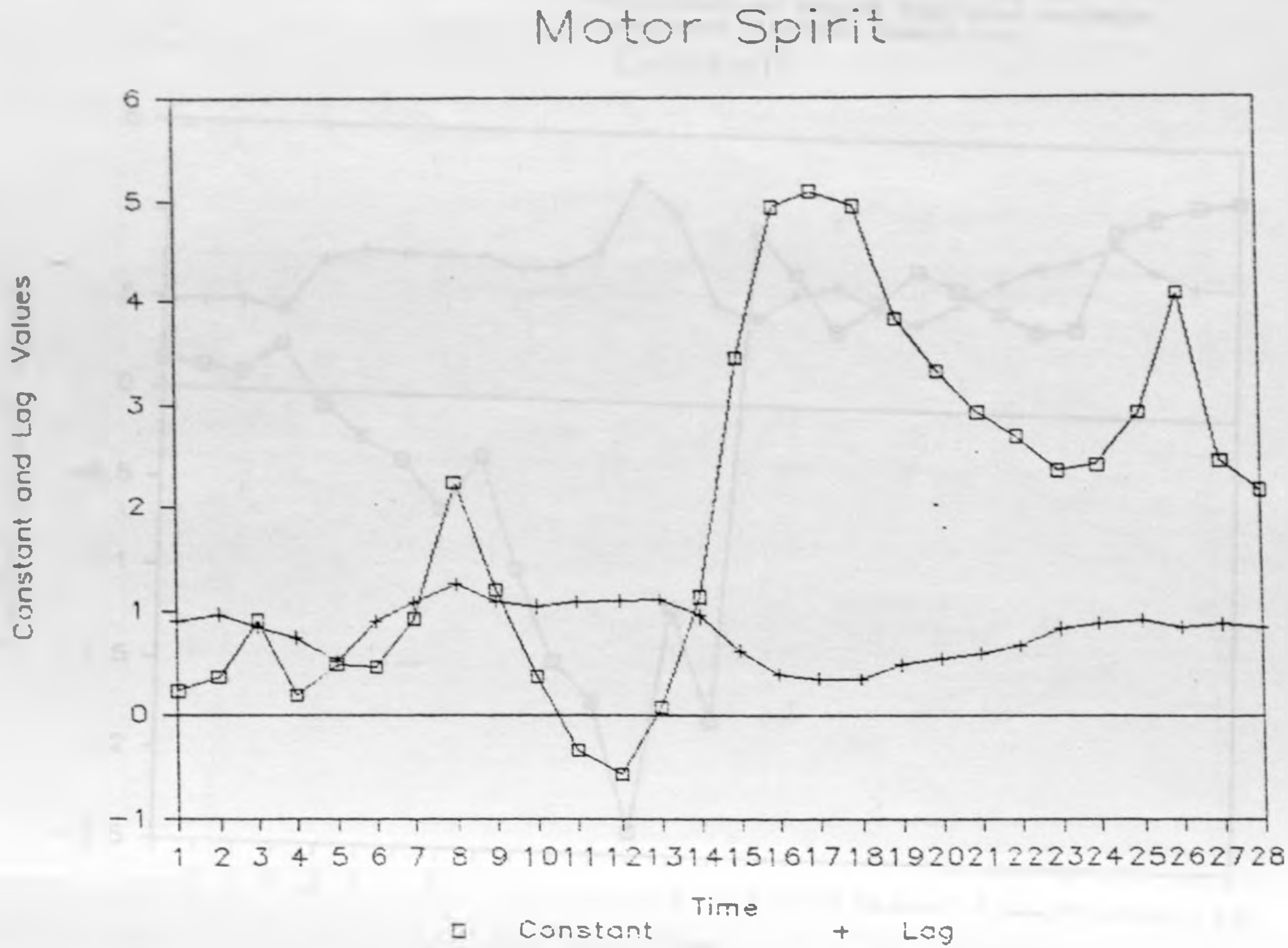


Figure 5.2: Trends in the constant term and the coefficient of lagged dependent variable associated with the demand for:

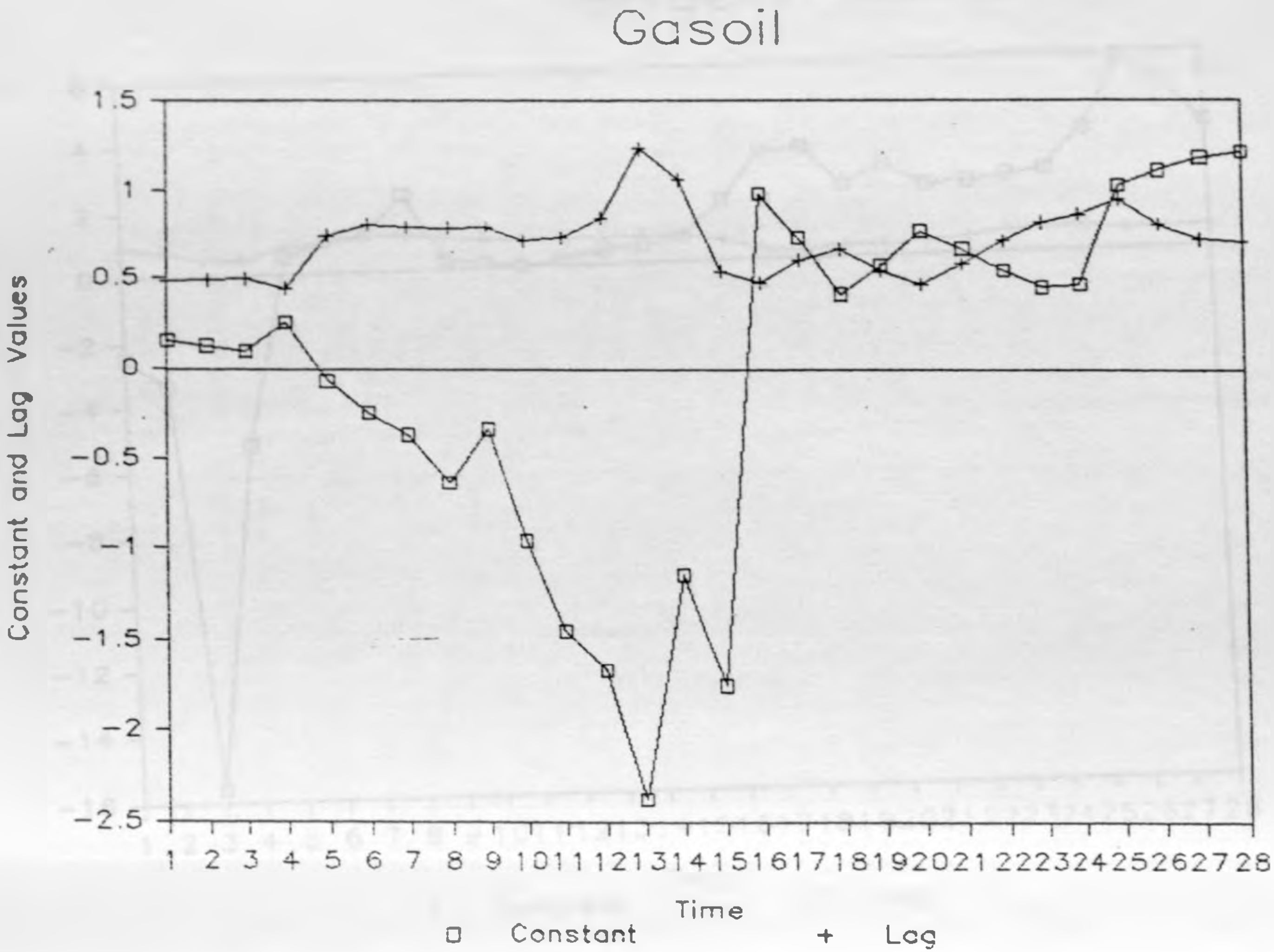


Figure 5.3: Trends in the constant term and the coefficient of lagged dependent variable associated with the demand for:

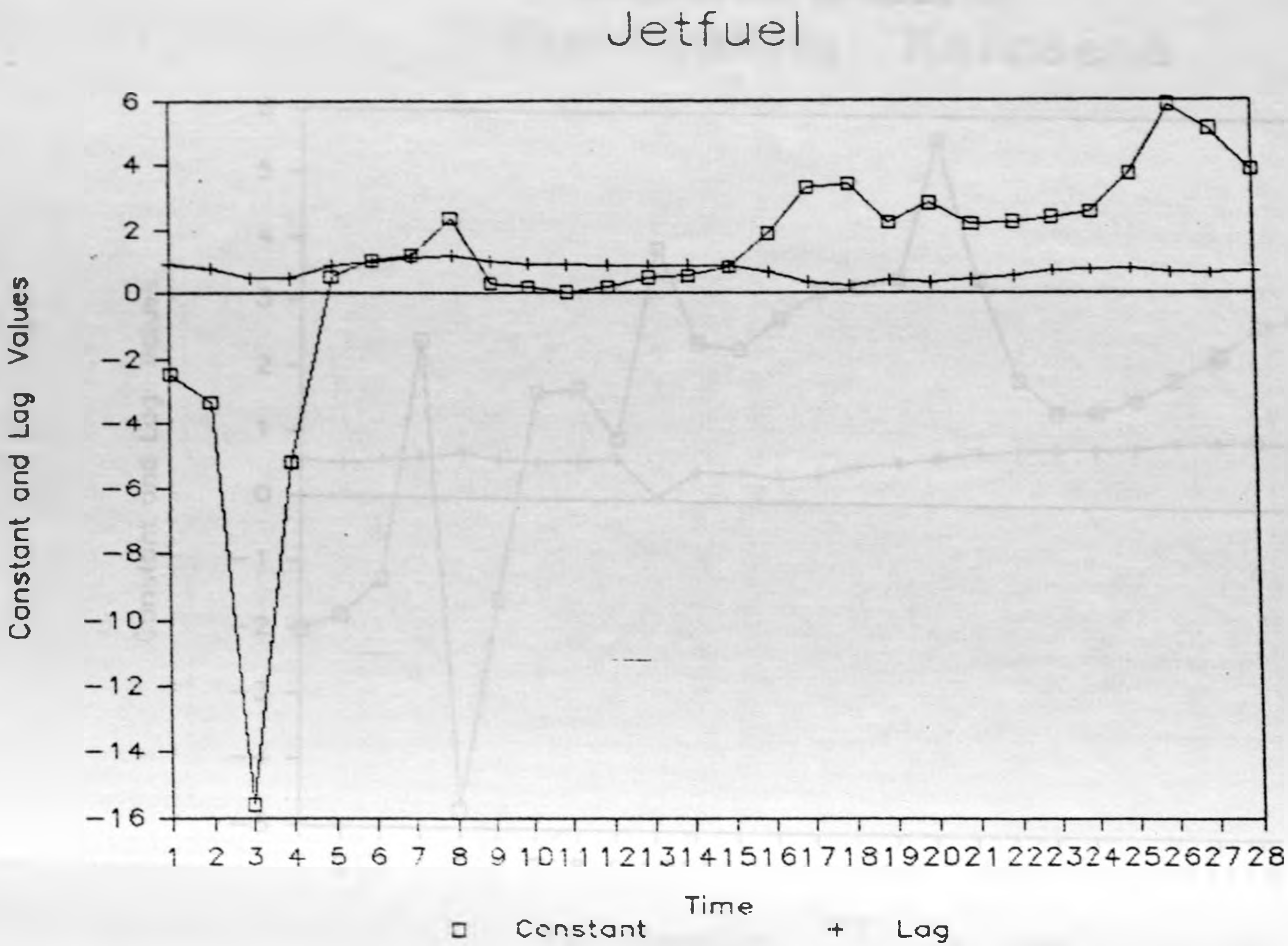


Figure 5.4: Trends in the constant term and the coefficient of lagged dependent variable associated with the demand for:

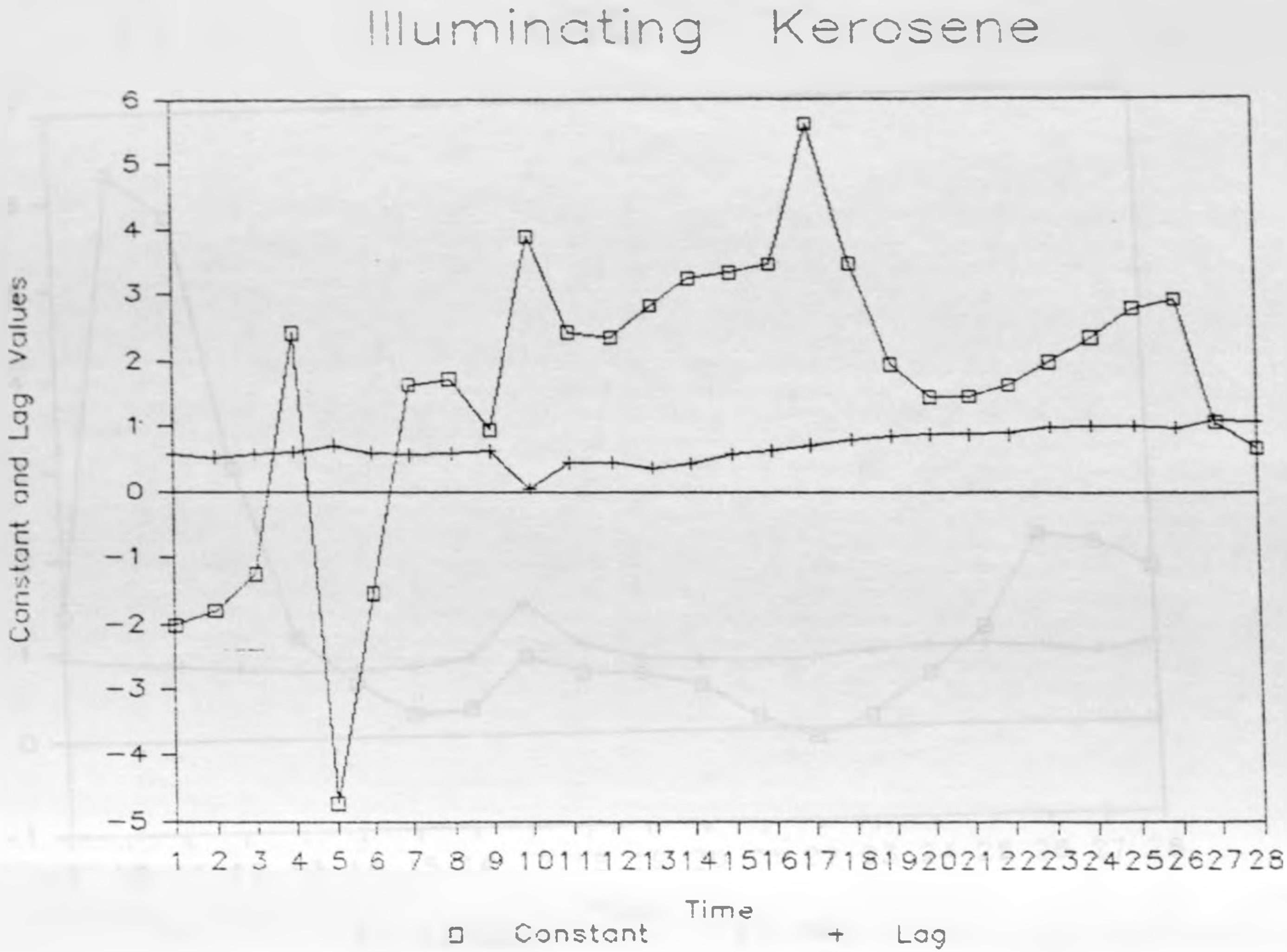


Figure 5.5: Trends in the constant term and the coefficient of lagged dependent variable associated with the demand for:

LPG

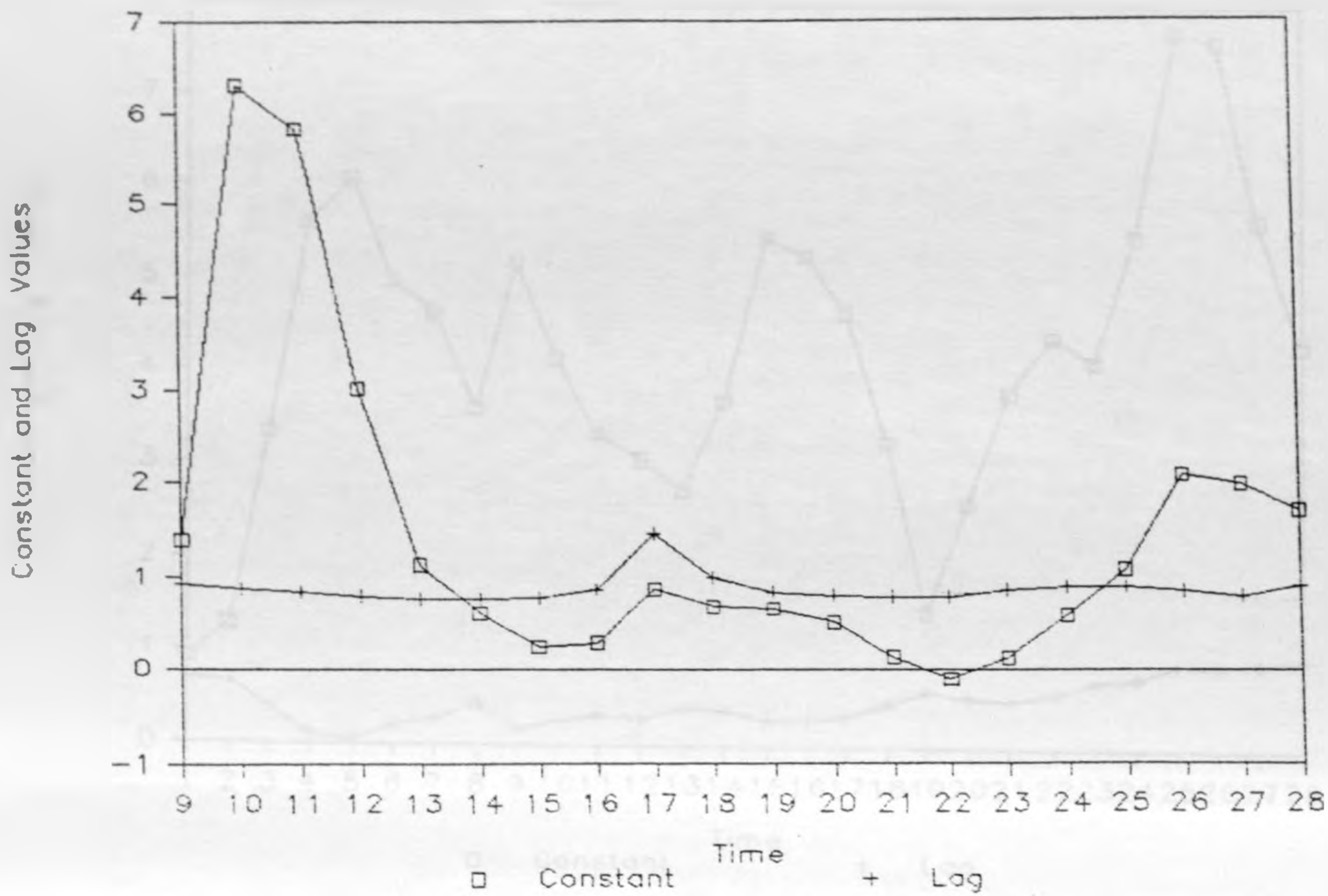


Figure 5.6: Trends in the constant term and the coefficient of lagged dependent variable associated with the demand for:

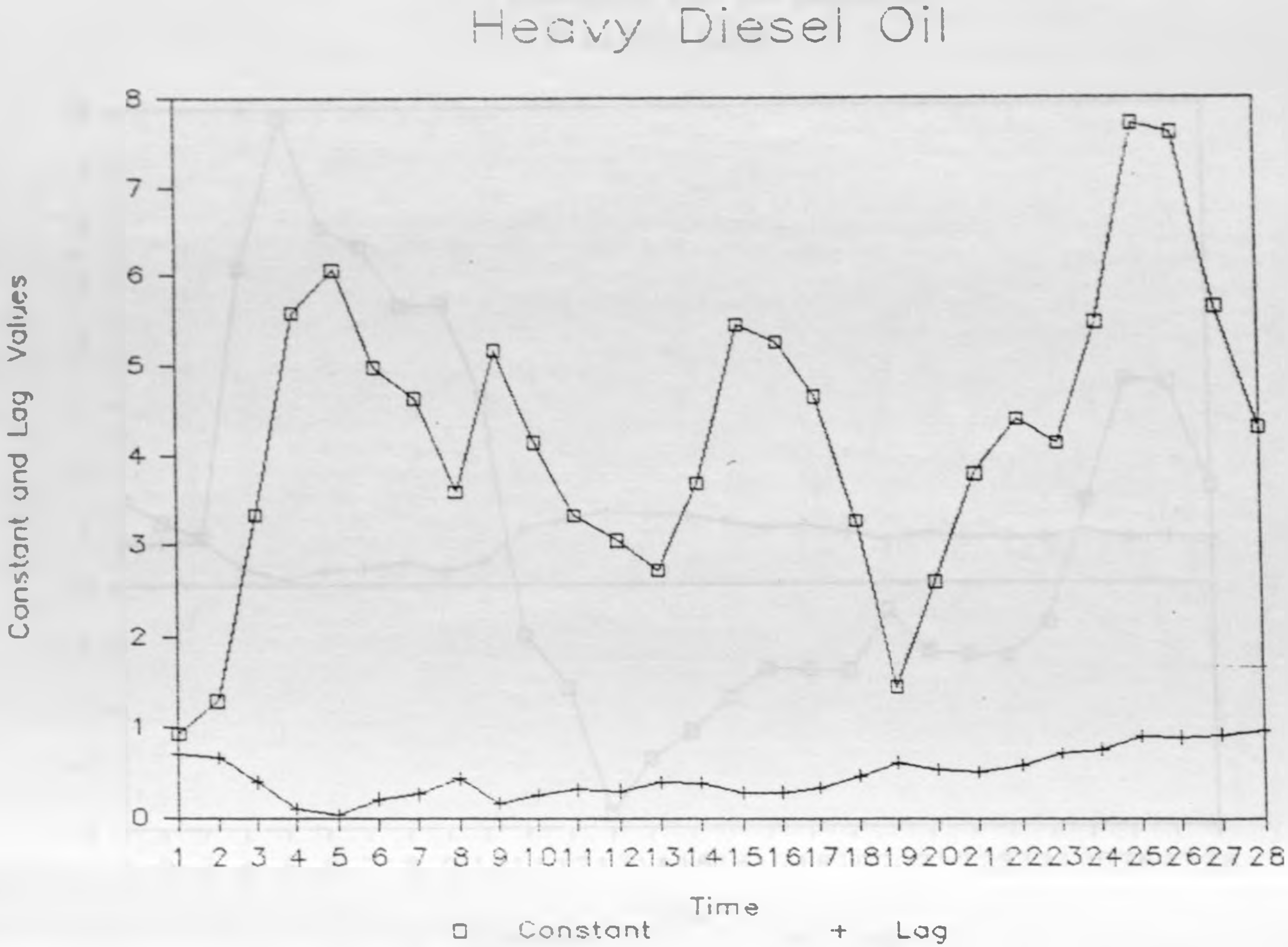


Figure 5.7: Trends in the constant term and the coefficient of lagged dependent variable associated with the demand for:

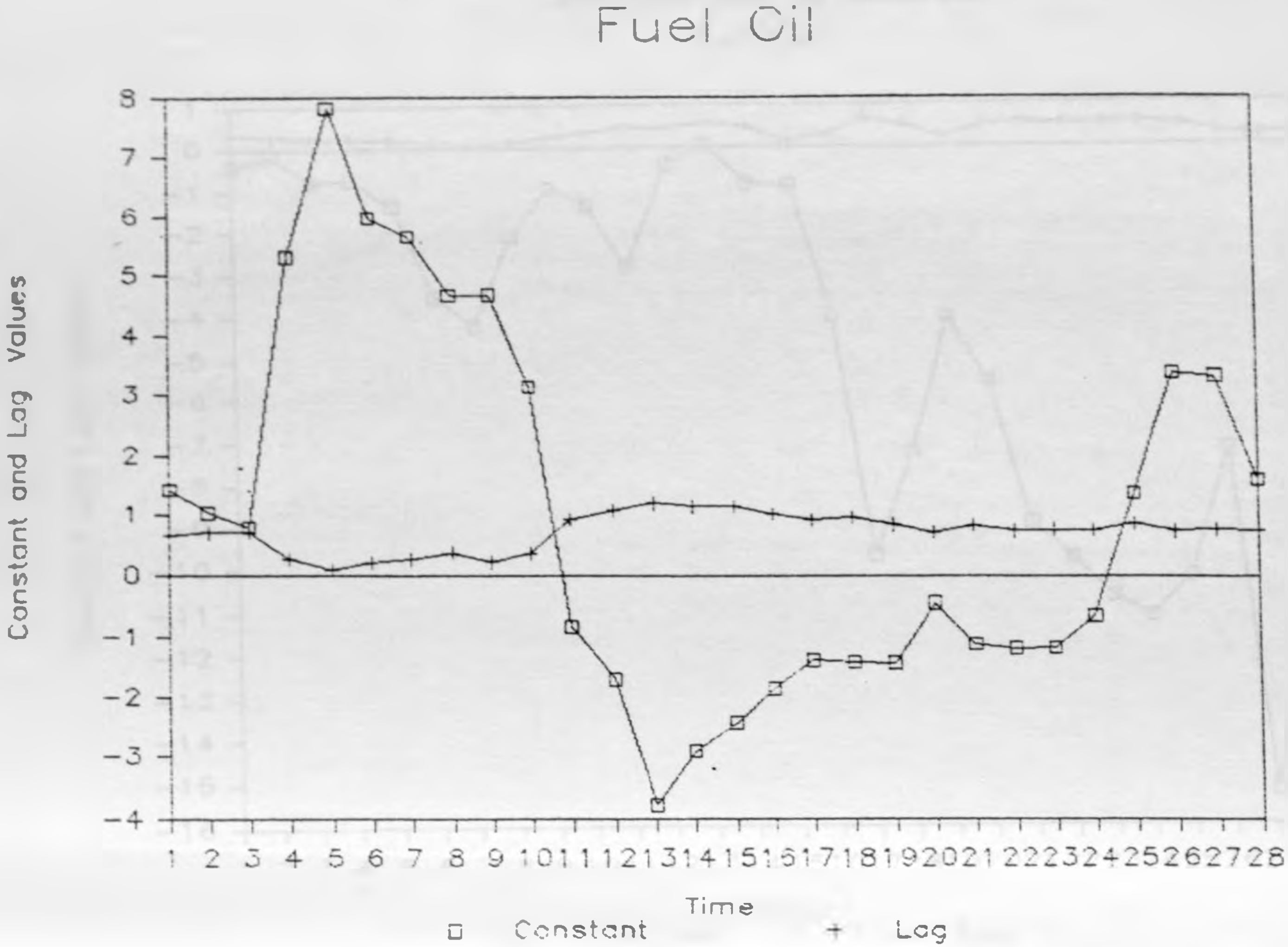


Figure 5.8: Trends in the constant term and the coefficient of lagged dependent variable associated with the demand for:
Coal

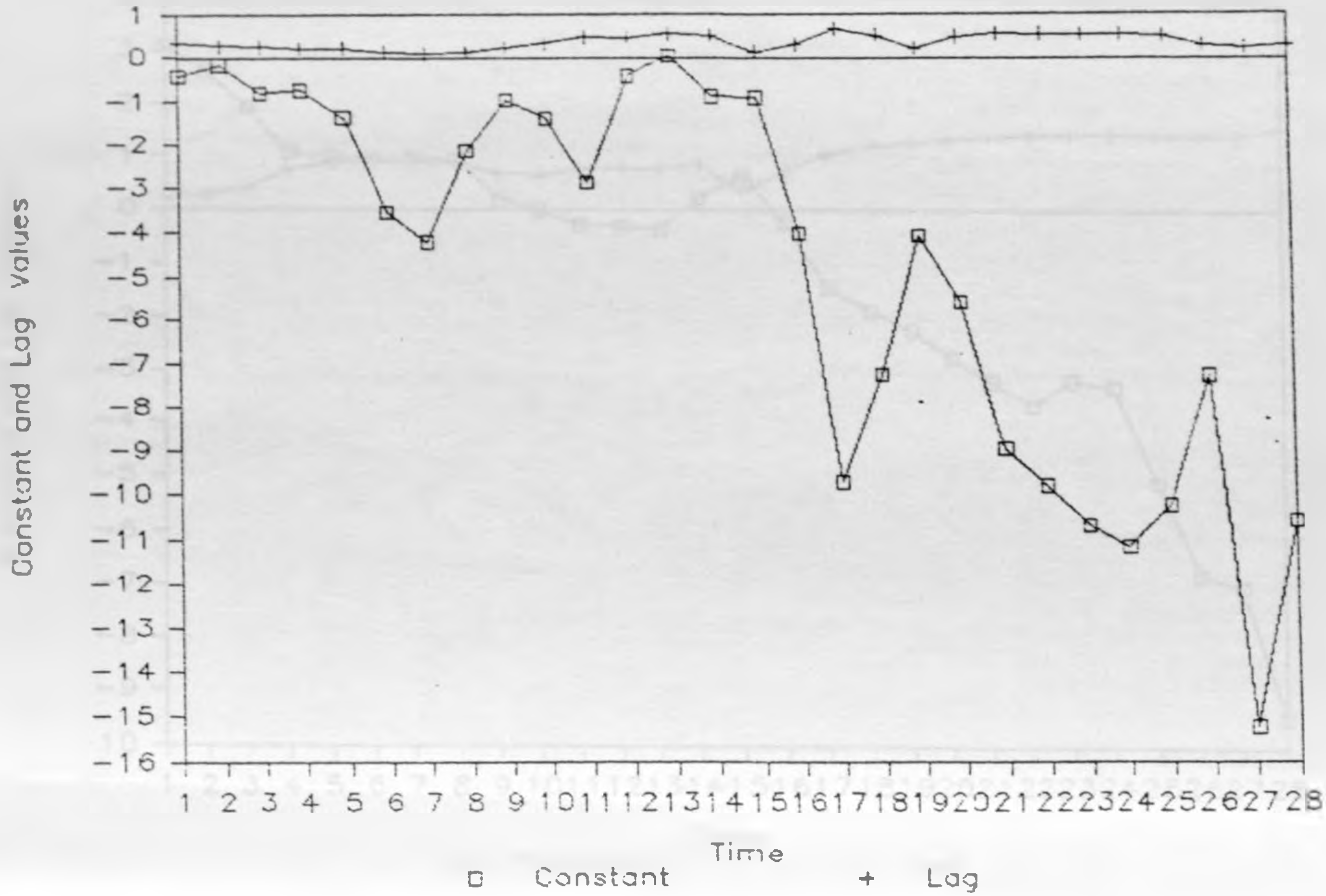


Figure 5.9: Trends in the constant term and the coefficient of lagged dependent variable associated with the demand for:

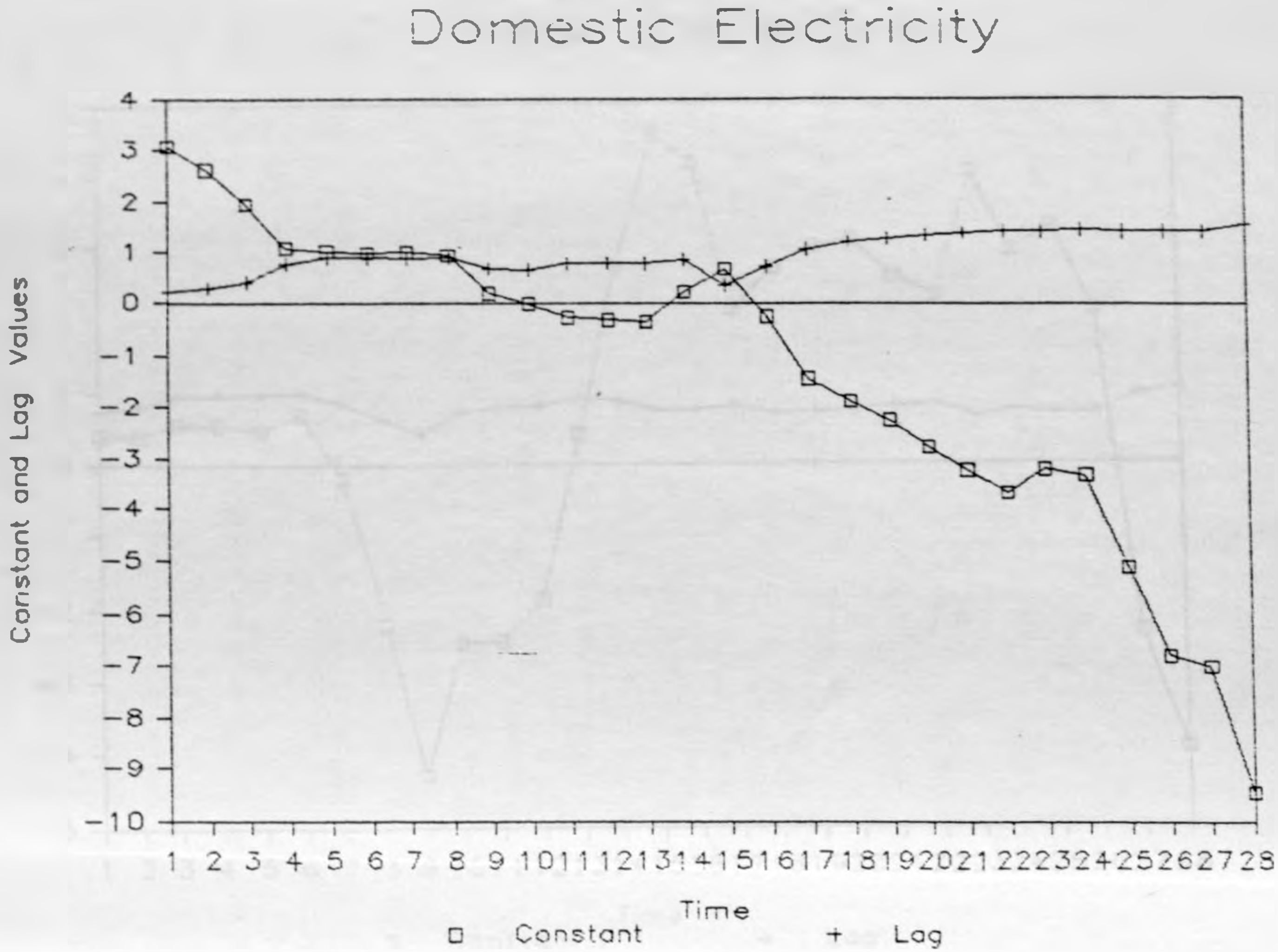


Figure 5.10: Trends in the constant term and the coefficient of lagged dependent variable associated with the demand for:

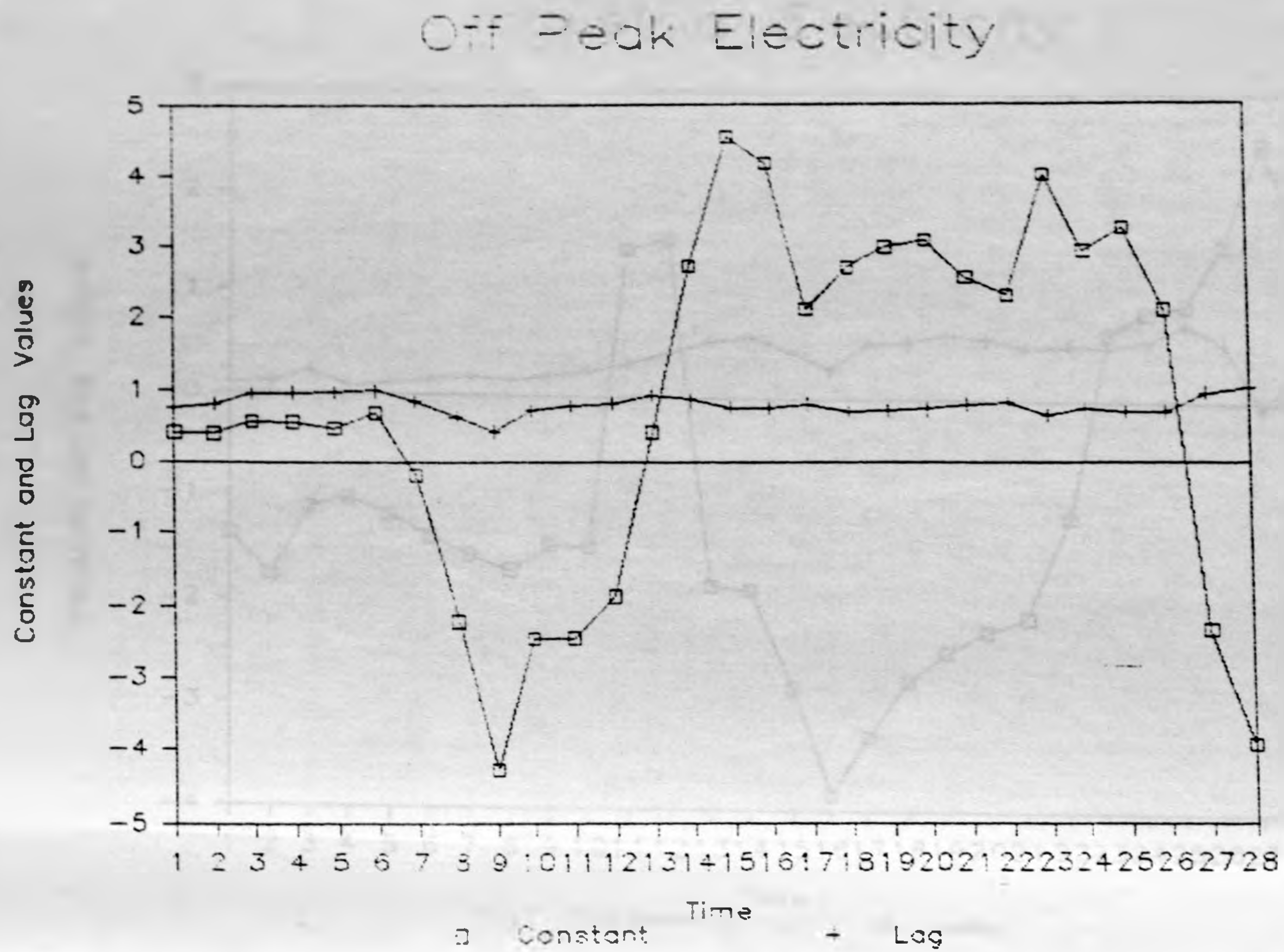


Figure 5.11: Trends in the constant term and the coefficient of lagged dependent variable associated with the demand for:

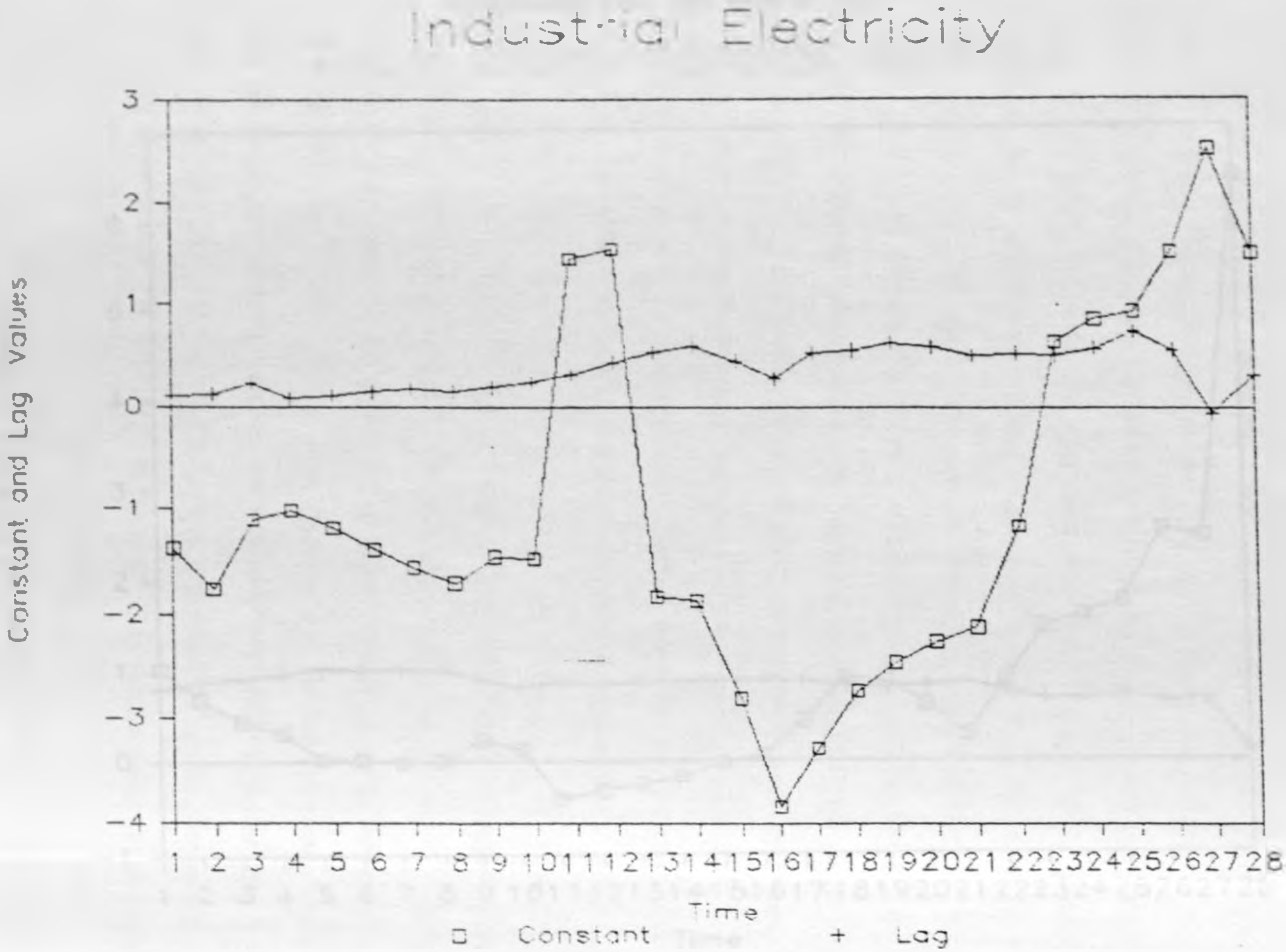
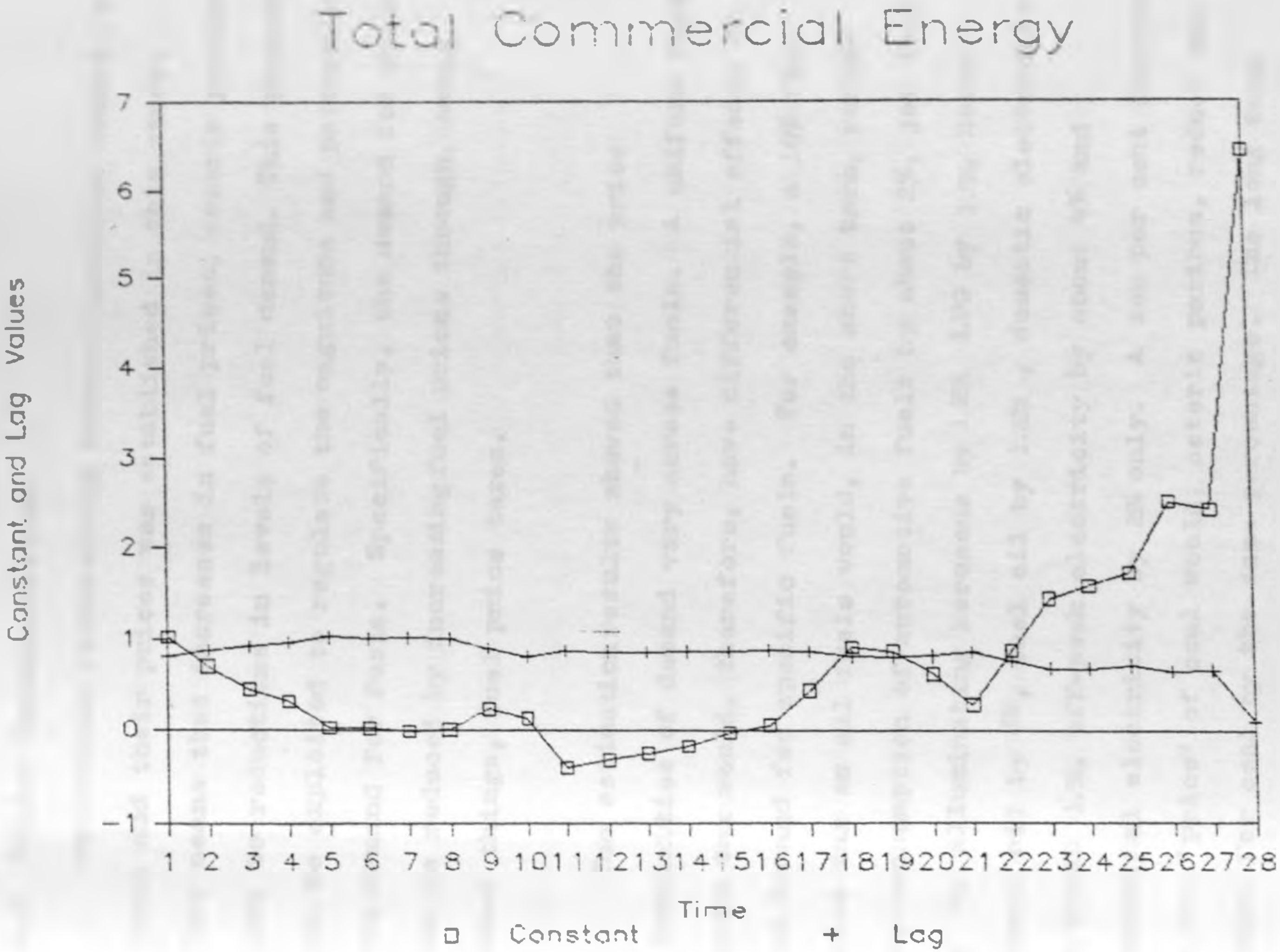


Figure 5.12: Trends in the constant term and the coefficient of lagged dependent variable associated with the demand for:



CHAPTER VI

POLICY RECOMMENDATIONS AND AREAS FOR FURTHER RESEARCH

6.1 Policy Recommendations:

An inverse relationship between levels of demand for fuels and their prices was established in this study. This means that increases in fuel prices, ceteris paribus, lead to reductions in levels of fuel demand. This phenomenon can be exploited to regulate the magnitude and pattern of the demand for fuels. Specifically, the demand for fuels can be reduced by increasing fuel prices through, among other things, fuel price taxes.

The estimation results showed that the price elasticities of demand vary across fuels. A uniform fuel price tax would, therefore, have differential effects on the demand for specific fuels. For example, a 10% fuel price tax on all fuels would, in the short term, reduce the consumption of automotive fuels by about 2%, jet fuel by .5%, illuminating kerosene by 1.25%, LPG by 1.5%, heavy diesel oil by .5%, fuel oil by 1.33%, domestic electricity by about 1.5%, off-peak electricity by about 4% and industrial electricity by .25% only. A ten per cent increase in the 'price' of coal would, ceteris paribus, reduce the demand for coal by the same percentage. The long term impacts would however be slightly stronger for all fuels. For example, a 10% fuel price tax would, in the long term, reduce the consumption of motor spirit by 9%, gas oil by 14%, illuminating kerosene by 5.5%, LPG by 5.5%, coal by more than 15% and off-peak electricity by 30%[1].

Since the consumption of most fuels is not highly responsive to changes in fuel prices, policy oriented fuel price increases cannot significantly reduce the consumption of fuels. This is the case even in the long term after economic units have had an opportunity to make the necessary fuel-use adjustments in response to the initial fuel price changes. Policy oriented fuel price adjustments should, therefore, be significantly greater than the intented reductions in the consumption of fuels. For example, a 50% price increase is necessary to reduce the consumption of automotive fuels by 10% in the short term. To achieve the same reductions in the consumption of other fuels, the requisite fuel price increases would be 200% for jet fuel, 80% for illuminating kerosene, 67% for LPG, 200% for heavy diesel oil, 75% for fuel oil, 67% for domestic electricity, 25% for off-peak electricity, and about 10% for coal. The fuel price increases to reduce the consumption of the fuels by 10% in the long-run would be slightly lower for all the fuels .

To achieve even very modest reductions in the consumption of fuels, the required fuel price adjustments

1. These required fuel price increases assume that incomes remain constant.

are very high. Such reductions can, however, be achieved through a combination of acceptable price increases and other policy tools such as rationing, regulations to reduce leisure-related motoring in the case of automotive fuels, duty and sales tax incentives to promote incremental investments on fuel - efficient industrial equipment, general education on efficient fuel use, and conservation campaigns. The policy combination would be dictated by the specific fuel's price elasticity of demand, the magnitude of the desired reduction in fuel consumption, and how soon such a reduction is expected to be achieved. While duty and sales tax incentives, education and conservation campaigns achieve results only in the long-run, rationing and controls on leisure-related motoring reduce the consumption of affected fuels immediately.

Owing to low price elasticities of demand for most fuels, energy users bear a bigger share of the fuel price adjustment burden than the firms involved in the procurement/production and distribution of fuels. This is the standard result of tax impositions on price in elastic products, compounded in Kenya by the fact that most of the fuels are imported, suggesting the existence of linearly horizontal supply curves for such fuels.

In that case, energy users bear the entire fuel price adjustment burden[2]. For this reason, policy related fuel price increases could accentuate income distribution inequalities[3]. Such increases should, therefore, be imposed selectively and only after due consideration has been given to the socio-economic status of the end-users of specific fuels. Since illuminating kerosene is used primarily by poor rural and urban households mainly for lighting and cooking, it should be kept free of taxation.

Low price elasticities of demand for certain fuels also indicate that the fuel requirements of the end-users of such fuels are inflexible due to either the absence of alternative fuels or the high costs of appliances using such alternative fuels. Such end-users would find it hard to adjust to increases in the prices of their preferred fuels. This seems the case with non-industrial fuels for which substitution possibilities appear limited, and whose use is likely to be dictated by mere availability. The implication is that policy oriented price increases for such fuels do not make for the provision of basic energy

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2. See Meier (1986 : p. 43 table 4.a)

3. It is assumed that producers and distributers of commercial energy in Kenya are economically better off compared to the house-hold end-users and should therefore bear a bigger share of the fuel tax burden on equity grounds. It is also assumed that the benefits from fuel tax revenue are distributed equitably.

needs and are likely to precipitate loss of welfare. On this account, taxes on illuminating kerosene, LPG and domestic electricity should be modest and imposed only as a last resort.

The income elasticities of demand for most of the fuels are higher than the price elasticities[4]. This means that the low negative fuel price effect would be dampened by the higher positive income effect on the demand for the fuels. As an example assuming a 10% fuel price tax on gas oil at a time when incomes are increasing at 10%, the demand for gas oil would still increase by about 6%. A 10% fuel price tax would not reduce the demand for gas oil if incomes grow by 2.5% only. The increases in incomes necessary to completely wipe-out the effect of a 10% fuel price tax in the short term are 9% for motor spirit, 1% for jet fuel, 1.5% for LPG, 8% for heavy diesel oil, 2.9% for fuel oil, 20% for coal, 50% for domestic electricity, 10% for off-peak electricity, and 1% for industrial electricity. The implication is that at a time when the economy is enjoying even very modest rates of growth, policy oriented fuel price increases would not on their own significantly reduce the demand for most fuels, and would require the support of other policy tools as suggested earlier. Back-up policies would be especially necessary to reduce the demand for jet fuel, LPG, fuel oil and industrial electricity.

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4. The only exceptions are coal, domestic electricity, and off-peak electricity.

Changes in the spatial population distribution and the relative importance of different sectors in the economy affect the demand for fuels. A 10% increase in the proportion of the population living in Nairobi would, ceteris paribus, increase the demand for motor spirit, gas oil, jet fuel, LPG, domestic electricity and off-peak electricity by 6.9%, 8.75%, 16%, 1.92%, 15.8% and 3.4% respectively; but reduce the demand for illuminating kerosene, heavy diesel oil, coal and off-peak electricity by 2.14%, 12.29%, 4.54% and 7.84% respectively. A 10% increase in the proportion of total monetary output accruing to agriculture would increase the demand for motor spirit, gas oil, illuminating kerosene, fuel oil, domestic electricity and industrial electricity by 1.14%, .23%, 3.41%, 6.5%, 5.5% and 16.7% respectively; but reduce the demand for jet fuel, LPG, heavy diesel oil, coal and off-peak electricity by 2.5%, 5.71%, 6.28%, 12.1% and 7.25% respectively.

Similarly, a 10% increase in the proportion of monetary output accruing to manufacturing would, ceteris paribus, increase the demand for motor spirit, gas oil, jet fuel, illuminating kerosene, heavy diesel oil, fuel oil, domestic electricity, industrial electricity, and off-peak electricity by 9.89%, 9.25%, 19.34%, 14.03%, 18.8%, 3.91%, 8.07%, 6.71% and 5.6% respectively; but reduce the demand for LPG and coal by .56% and 39.33% respectively. A similar increase in the proportion of monetary output accruing to transportation would increase the demand for motor spirit, gas oil, fuel oil, coal domestic electricity and industrial electricity by 9.21%, 7.12%, 7.40%, 6.55%, 9.25% and 6.50% respectively, and reduce the consumption of jet fuel, illuminating kerosene, LPG, heavy diesel oil, and off-peak electricity by 13.56%, 1.7%, 15.31%, 3.58% and 10.51% respectively.[5] An increase in the proportion of total monetary output accruing to the service sector would reduce the demand for all the fuels except for LPG, coal and domestic electricity.

These differential effects of increases in the relative importance of different sectors on the demand for different fuels imply that the strategy for future economic development will have a significant effect on the demand for future levels of demand for different fuels as well as total commercial energy.

If such strategy leads to increased dominance of the service sector which consists of wholesale and retail trade, hotels and restaurants, finance, insurance real estate and business services, this would lead to reduced demand for all fuels. However, a development strategy that increases the relative importance of the manufacturing and repair sectors would increase the demand for all fuels. A gradual increase in urban population would increase the

5. The transport sector's contribution includes contribution from storage and communications.

consumption of motor spirit, gas oil and off-peak electricity, but reduce that for illuminating kerosene and heavy diesel oil. On balance, an increase in urban population would lead to an increase in the overall demand for commercial.

Planners need to assess the energy implications of the future development strategies. A development strategy that increases the relative importance of certain sectors of the economy will affect the consumption of different fuels differently, and hence the commercial energy demand.

The greatest conservation potential is in the consumption of motor spirit, jet fuel, illuminating kerosene, heavy diesel oil and off-peak electricity, while great potential for improvements in energy efficiency exist in the consumption of coal and industrial electricity. Such potential can be exploited by giving financial incentives such as soft loans and selective reduction of import tariffs to promote acquisition of more efficient industrial plants and retrofitting of existing equipment. The incentives should be preceded by an assessment of the optimal tax and duty remissions based on cost-benefit analysis and be implemented so that incremental efficiency and conservation investments can be made.

6.2 Areas for Further Research

There is need to generate data for analysing fuel demand at specific sectors and economic units level. Different economic units have different fuel-use characteristics, a fact which should be taken into consideration in the analysis of demand for energy. This is important for eliciting the correct behavioural energy-demand responses and developing appropriate guidelines for energy policy.

Non-commercial energy contribute significantly to the overall energy balance in Kenya. It is especially important in the rural economy where there is a subtle interface between commercial and traditional fuels for certain end-users. There is need to develop and apply energy demand models that take such link into direct consideration so that the impact of commercial energy policies on traditional fuels can be explicitly analyzed [6].

Some aspects of the energy sector in Kenya suggest that the structure of energy demand has been changing. The gradual introduction of differential taxes on specific fuels, the commissioning of the pipeline in 1978, the shift in the use of coal from rail transport to industrial use, and the introduction of electricity in new areas are

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6. An attempt has already been made towards the development of such models. See: Pachauri (1983)

suggestive of such change. There is need to locate any possible structural breaks in the demand for individual fuels so as to create a better understanding of the energy demand system and evaluate the usefulness of fuel demand models in energy forecasting and planning.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Kenya is a developing country with rapidly increasing commercial energy consumption. Its proven domestic commercial-energy resource-base is poor. Efforts aimed at the exploration and development of domestic resources have so far been fruitful in the electricity subsector only where hydro and geothermal sources are used to produce electricity. Oil exploration has yet to show significantly positive results.

Oil accounts for 75% of the country's total commercial energy consumption. The country relies on external markets for all its oil and coal requirement. Unfortunately, the international oil industry has been in a state of flux in the last 15 years or so, which saw the change in de jure ownership of the world's major oil fields from oil majors to the oil producing countries themselves. One consequence of that change was the destruction of the system of checks and balances which guaranteed smoothness in oil trade and forestalled tendencies towards cyclical behaviour experienced by other internationally traded commodities. As a result, very wide oil price fluctuations are now possible.

Between 1970 and 1981, the average price of imported Middle East crude oil increased about 19 fold from US$ 1.82 to US$ 34.52. Such crude oil price escalation led to an increase in the domestic prices of petroleum products and electricity, an oil trade deficit amounting to K£ 257.4 million in 1985, a deterioration in the overall balance of trade, a reduction in the rate of capital formation, a reduction in the rate of increase in wage employment and a slow down in overall economic growth.[1]

The consumption of total commercial energy increased from 895,600 tonnes of oil equivalent in 1963 to 2,042,100 tonnes in 1985. Over the same period, the consumption of petroleum products increased by about 5% p.a., and that for electricity by about 8% p.a. on average.

Under these circumstances, a regulation of the rate of increase in the consumption of commercial energy is necessary to reduce the country's vulnerability to changes in energy costs. A clear understanding of the structure of demand for commercial energy is imperative in the evolution of appropriate tools for such regulation. In this regard, it was found desirable to investigate the inter-relationships that underlie the demand for commercial fuels as a means to understanding and explaining the structural behaviour of such a system in Kenya. This was the primary objective of the study.

An exploration of the relevant literature showed that there are many behavioural models that have been used in carrying out the required investigation, including the static linear and non-linear models, static and dynamic transcendental logarithmic models, dynamic constant-elasticities models, programming models, and others. A distinctive feature of the models is that all of them are built on simplifying assumptions and are approximations of

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1. These rates of increase in the consumption of petroleum products and electricity were lower during the periods of rapidly increasing energy prices such as between 1973 and 1982.

complex economic relationships which constitute energy demand.

It was shown in this study that in a two-stage optimization process that appears to characterize energy-use decisions, the prices of energy-using equipment the price of energy, aggregate production, and the structure of the economy influence the derived demand for energy. For purposes of analysis, commercial energy was disaggregated into 11 fuels and three sets of demand functions were developed and estimated for each fuel, including a basic dynamic log-linear model in prices, income and lagged fuel consumption, using half-yearly data for 1963-1985 obtained from secondary sources.

The estimation results showed negative but low price elasticities and positive income elasticities of demand for all fuels except kerosene which was considered inferior on this account. The coefficients of the lagged fuel-consumption of all the fuels fell within the expected range except for residential electricity. The results generated a wide range of elasticities of demand for different fuels with respect to the proportions of GDP accruing to different sectors of the economy, and showed differences in conservation and efficiencies with which different fuels are used.

The models performed well on broad theoretical and statistical criteria, with reasonably large coefficients of determination and estimated F-values. The majority of the estimated parameters were significantly different from zero at least at 5% level, and individual sets of the fuel demand models seemed to explain the phenomenon in question sufficiently.

The results showed that the demand for most fuels is more responsive to changes in incomes than prices, and that the impact of a change in the conditions of demand is felt more in the long-run than the short-run. The structure of the economy has a definite effect on the demand for fuels. In particular, the share of total monetary output accruing to manufacturing and repair has a positive effect on the demand for all fuels, and the service sector's share has a negative effect on the demand for all fuels except domestic and industrial electricity. Urbanization showed a positive influence on all fuels except illuminating kerosene and heavy diesel oil, while the effect of the share of total monetary GDP accruing to agriculture was positive for all fuels except heavy diesel oil. The impacts of the share accruing to transport, refrigeration and communications were mixed.

Some policy issues emerged from this investigation. These include the inadequacy of price oriented policies in controlling the demand for commercial energy except when they are backed up by other policies, the possibility of price-oriented energy policies causing difficulties for certain categories of energy users in the country, the importance of giving conservation incentives selectively on fuel basis, and close relationships between the development strategy and future levels of energy demand.

Areas found to merit further investigation included the analysis of energy demand at a more micro-level, the development and application of energy demand models that take the link between commercial and non-commercial energy into direct consideration, and the exploration of locations of possible structural breaks in the demand for individual commercial fuels.

Appendix A. Estimated crude oil procurement and processing cost build-up, February 1986

Types of Crude oil imports / Cost basis (US$ per barrel)	Arabian light	Arabian medium	Arabian heavy	Iranian light	Iranian medium	Arabian light	Qatar medium berri	Zakum	Kuwait	Murban	Weighted average
% Volume mix	3.2	0.2	12.1	3.8	17.0	15.6	5.0	13.0	2.7	27.4	100
FOB	17.0	16.20	15.0	17.0	16.20	17.11	17.10	17.10	16.10	17.15	16.672
Freight	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
Cost and freight	17.75	16.95	15.75	17.75	16.95	17.85	17.85	17.85	16.85	17.90	17.422
Insurance (.15% C&F)	.027	.026	.024	.027	.026	.027	.027	.027	.025	.027	.026
CIF	17.777	16.976	15.774	17.777	16.976	17.887	17.877	17.877	16.875	17.927	17.448
Wharfage (1.5% C&F)	.267	.255	.237	.267	.255	.269	.268	.268	.253	.269	.262
Import licence (1% C&F)	.178	.170	.158	.178	.170	.179	.179	.179	.169	.179	.174
Cost insurance, freight, wharfage and licence	18.22	17.401	16.250	18.313	17.488	18.423	18.426	18.426	17.384	18.467	17.974
Ocean loss (.5% CIFWL)	1.975	1.849	1.851	2.042	2.008	2.022	2.263	2.506	2.005	2.363	2.160
Crude procurement and processing cost	20.298	19.337	18.101	20.355	19.496	20.445	20.698	20.932	19.389	20.830	20.140

Source: Ministry of Energy.

Appendix B.1 Prices of premium motor spirit effective from 13th June 1986 (KSh per 1000 litres)

Town	Bridging allowance[1]	Wholesale price	Town delivery allowance	Retail price2
Mombasa	-	7,308	38	7,720
Nairobi[3]	-	7,612	38	8,020
Sagana	96.15	7,712	38	8,120
Naro Moru	139.60	7,752	38	8,160
Nanyuki	146.80	7,762	38	8,170
Gilgil	96.15	7,712	38	8,120
Nakuru	117.85	7,732	38	8,140
Eldoret	219.25	7,832	38	8,240
Londiani	168.85	7,782	38	8,190
Kisumu	219.25	7,832	38	8,240

Source: Ministry of Energy.

Notes:
1. This allowance is for Kenya Railways tariff, from Nairobi to other towns.
2. The retail prices include a fixed retail margin amounting to KSh 370 per thousand litres for all specified towns.
3. The wholesale prices for Nairobi and Mombasa differ by an amount equal to the Pipeline tariff of KSh 304.

Appendix B.2 **Prices of regular motor spirit effective from 13th June 1986** (KSh per 1000 litres)

Town	Bridging allowance	Wholesale price	Town delivery allowance	Retail prices
Mombasa	-	6,938	38	7,340
Nairobi	-	7,242	38	7,640
Sagana	91.90	7,332	38	7,730
Naro Moru	133.40	7,372	38	7,770
Nanyuki	140.30	7,382	38	7,780
Gilgil	91.90	7,336	38	7,730
Nakuru	112.65	7,352	38	7,750
Eldoret	209.45	7,452	38	7,850
Londiani	161.05	7,402	38	7,800
Kisumu	209.45	7,452	38	7,850

Source: Ministry of Energy.

Note: Retail prices include a fixed retail margin amounting to KSh 360 for all towns.

Appendix B.3 Prices of illuminating kerosene effective from 13th June 1986 (KSh per 1000 litres)

Town	Bridging allowance	Wholesale prices	Town delivery allowance	Retail prices
Mombasa	-	3,149	38	3,470
Nairobi	-	3,453	38	3,770
Sagana	104.45	3,563	38	3,880
Naro Moru	151.70	3,613	38	3,930
Nanyuki	159.60	3,613	38	3,930
Gilgil	104.45	3,563	38	3,880
Nakuru	128.10	3,583	38	3,900
Eldoret	238.40	3,693	38	4,010
Londiani	183.25	3,643	38	3,960
Kisumu	238.40	3,693	38	4,010

Source: Ministry of Energy.

Note: Retail prices include a fixed retail margin of KSh 360 for all towns.

Appendix B.4 Prices of gasoil effective from 13th June 1986 (KSh per 1000 litres)

Town	Bridging allowance	Wholesale prices	Town delivery allowance	Retail prices
Mombasa	-	4,639	38	5,000
Nairobi	-	4,943	38	5,350
Sagana	111.70	5,063	38	5,420
Naro Moru	162.35	5,113	38	5,470
Nanyuki	170.60	5,113	38	5,470
Gilgil	111.70	5,063	38	5,420
Nakuru	137.00	5,083	38	5,440
Eldoret	255.15	5,203	38	5,560
Londiani	196.10	5,143	38	5,500
Kisumu	255.15	5,203	38	5,560

Source: Ministry of Energy.

Note: Retail prices include a fixed retail margin of KSh 319 for all towns.

Appendix B.5 **Prices of heavy diesel oil effective from 13th June 1986**
(KSh per 1000 litres)

Town	Bridging allowance	Wholesale prices	Town delivery allowance
Mombasa	-	2,665.00	56
Nairobi	296.10	2,961.10	56
Sagana	356.05	3,021.65	56
Naro Moru	391.05	3,050.05	56
Nanyuki	408.55	3,073.55	56
Gilgil	356.65	3,021.65	56
Nakuru	382.60	3,047.60	56
Eldoret	451.85	3,116.85	56
Londiani	408.55	3,073.55	56
Kisumu	469.15	3,134.15	56

Source: Ministry of Energy.

Note: This product is not retailed but is sold in large quantities to industrial users.

Appendix C Prices of different petroleum products
(KSh per litre)

Year	LPG	Aviation/Jet spirit /fuel	Motor spirit	Kerosene	Gas oil	HDO	Fuel oil
1963		.76	.90	.82			
1964		.78	.92	.84			
1965		.83	.98	.84			
1966		.86	1.02	.84			
1967		.87	1.03	.84	.77	.40	.30
1968	1.64	.87	1.03	.92	.77	.40	.30
1969	1.60	.87	1.03	.90	.77	.40	.30
1970	1.78	.87	1.03	1.00	.75	.39	.31
1971	2.07	.92	1.09	1.16	.82	.34	.34
1972	2.25	.92	1.09	1.24	.82	.34	.34
1973	2.25	1.09	1.28	1.18	.84	.38	.38
1974	2.25	1.63	1.92	1.24	1.16	.72	.63
1975	3.32	2.09	2.47	1.30	1.36	.90	.75
1976	3.32	2.17	2.56	1.50	1.77	1.11	.87
1977	3.33	2.33	2.75	1.58	1.94	1.16	.95
1978	3.32	2.45	2.89	1.58	2.18	1.54	1.15
1979	3.84	2.95	3.48	1.76	2.41	1.70	1.23
1980	4.25	4.01	4.73	2.30	3.23	2.28	1.59
1981	5.20	5.34	6.30	2.92	4.41	3.13	2.08
1982	5.20	6.19	7.30	3.80	5.48	3.13	2.14
1983	5.20	6.58	7.76	3.90	5.48	3.13	2.14
1984	6.83	7.07	8.34	4.37	5.94	3.43	2.35
1985	6.83	7.07	8.34	4.37	5.94	3.43	2.35

Source: Ministry of Energy, Kenya Petroleum Sector Data.

Appendix D. Intake of crude oil at KPRL, selected years

Crude type		Country	Gravity	Intake in percentages 1978	1980	1982	1984	1986
Arabian light	)		33.9	24.1	28.8	30.8	2.9	1.3
Arabian medium	)		31.0	.8	22.2	1.8	.2	0
Arabian heavy	)	Saudi	27.9	0	2.9	8.7	12.1	1.3
Arabian light berri	)	Arabia	0	0	0	15.6	13.5	
Iranian light	)	Iran	33.9	21.0	0	2.4	3.8	0
Iranian mediumm	)		-	20.8	3.2	2.9	17.0	10.0
Qatar Marine	)	Qatar	36.7	16.6	17.2	0	5.0	0
Qatar Durkham	)		41.2	10.0	1.7	2.9	0	13.3
Kuwait		Kuwait	32.0	0	12.6	2.4	2.7	1.6
Zakum	)	United	40.1	5.3	9.6	3.6	13.3	9.0
Basrah	)	Arab	34.1	1.9	0	0	0	0
Murban	)	Emirates	39.6	0	2.1	23.0	27.4	50
Oman		Oman	-	0	0	8.8	0	0
Suez mix			-	0	0	9.4	0	0
Slops			-	0	.2	.2	.04	.05
Total				100	100	100	100	100

Sources: Republic of Kenya: Economic Survey. Government Printer, Nairobi. 1983, 1985 and 1987 issues.

Notes: 1. Gravity is measured in degrees API.

2. Figures for 1986 are provisional.

Appendix E Study Data

Sales of petroleum products (million litres)

Year	LPG	Motor spirit	Aviation spirit	Turbo fuel	Illuminating kerosene	Power kerosene	Light diesel oil	Heavy diesel oil	Furnace oil
1959	-	150.094	19.298	19.497	29.290	9.242	94.350	26.350	415.955
1960	-	155.099	25.262	32.267	34.308	8.020	105.460	27.535	427.913
1961	-	152.180	23.280	55.147	32.776	6.400	99.290	24.482	393.648
1962	-	154.640	14.756	74.431	37.350	6.423	109.008	24.739	410.650
1963	-	159.29	16.988	81.563	37.880	5.451	106.730	27.158	422.133
1964	-	161.754	14.029	83.918	42.460	4.601	114.058	26.644	447.124
1965	-	161.654	10.374	104.88	43.780	4.032	118.759	28.912	418.497
1966	-	169.996	11.583	154.194	44.880	3.814	134.729	32.140	438.858
1967	-	183.589	10.006	153.872	53.060	3.291	148.385	32.572	458.301
1968	8.530	196.767	6.868	176.942	57.790	2.891	176.919	35.404	419.457
1969	10.780	212.830	7.814	202.957	51.380	2.350	183.885	36.824	352.560
1970	12.760	235.148	8.442	224.540	56.948	1.496	190.027	42.327	392.073
1971	15.180	271.462	6.072	242.422	56.591	1.600	248.539	47.075	419.855
1972	18.190	292.537	6.797	278.425	66.579	1.569	277.792	50.223	452.650
1973	12.020	321.041	7.662	341.769	65.731	1.272	302.549	54.845	432.811
1974	12.360	311.487	7.786	318.881	67.674	.595	297.899	47.599	437.098
1975	13.741	324.474	8.429	377.042	70.571	.291	303.718	38.599	464.295
1976	14.700	333.553	8.281	407.490	68.052	.254	340.806	52.609	534.012
1977	16.400	310.764	7.192	351.596	74.590	.246	359.120	37.820	598.212
1978	16.900	328.512	7.540	347.420	87.120	.205	355.540	32.710	
1979	20.200	350.320	6.264	382.920	103.590	2.993	405.070	35.840	501.580
1980	21.500	348.928	5.400	403.560	99.300	.139	473.860	45.120	536.040
1981	21.100	346.260	7.076	398.460	102.780	.001	435.700	35.610	487.660
1982	20.900	312.388	6.100	326.890	95.350	-	432.800	32.020	496.830
1983	19.900	297.424	7.076	290.120	94.890	-	451.120	26.910	402.170
1984	21.600	298.432	6.496	300.90	94.420	-	487.320	29.230	477.570
1985	22.4	267.800	5.900	261.000	90.900	-	447.700	25.100	376.500

Source: Republic of Kenya. Statistical Abstract. Nairobi: Government Printer, 1963-1986 issues.

Appendix G Commercial energy conversion factors

Fuel	Litres per tonne of oil equivalent
LPG	1852
Aviation spirit	1402
Turbo fuel	1335
Motor spirit	1384
Illuminating kerosene	1274
Power kerosene	1234
Gasoline	1191
Heavy diesel oil	1171
Residual fuel oil	1058
All electricity	4000[1]
Coal	1.429[2]
Coke	1.493[3]

Sources: 1. Republic of Kenya (1978).

2. World Bank (1980a).

Notes: 1. These are kilowatt hours per tonne oil equivalent, calculated on input basis assuming a modern power station.

2. Figure shows tonnes of coal per tonne of oil equivalent.

3. These are tonnes of coke per tonne of oil equivalent.

Appendix H. Half-yearly Data

Priv. Cons./ H/Hold. K£ (1)	Pop. in Nairobi % (2)	Real GDP/ H/Hold K£ (3)	Renum./ H/Hold K£ (4)	Per Capita Real GDP K£ (5)	Per Capita Renum. K£ (6)	Manuf. & Repair Output K£ (7)	Sectoral Contribution to Monetary GDP: Agr.GDP % (8)	Manuf. Repair % (9)	Trans,Stor., Communication % (10)	Services % (11)
189.1	0.035	373.1	205.1	53.3	29.3	68.3	21.0	14.1	10.5	18.6
187.3	0.036	366.6	202.3	52.4	28.9	70.3	20.0	14.5	10.8	18.5
185.5	0.037	360.2	199.5	51.5	28.5	72.3	18.7	15.0	11.0	18.3
192.3	0.038	373.2	205.8	53.4	29.4	76.1	19.4	15.0	11.2	18.7
199.3	0.039	386.7	212.1	55.4	30.3	80.0	20.2	15.0	11.4	19.1
202.9	0.040	389.8	216.3	55.8	30.9	82.2	19.2	15.1	11.3	18.8
206.5	0.041	393.0	221.2	56.2	31.6	84.5	18.2	14.6	10.9	18.2
211.9	0.042	405.4	230.3	58.0	32.9	87.5	17.8	15.2	11.0	18.4
217.4	0.044	418.3	240.1	59.8	34.3	90.7	17.4	14.8	10.9	19.4
214.2	0.045	420.7	239.4	60.0	34.2	97.1	17.5	15.3	10.7	18.1
211.0	0.047	423.1	238.7	60.3	34.1	103.9	17.7	15.7	10.5	17.9
219.4	0.047	436.2	243.6	62.2	34.8	107.5	17.9	15.6	10.3	18.5
228.1	0.048	449.8	248.5	64.1	35.5	111.2	18.1	15.5	10.2	18.1
236.0	0.048	453.4	255.5	64.7	36.5	116.4	17.1	15.7	10.0	18.9
244.1	0.048	457.1	262.5	65.4	37.5	121.9	16.2	16.0	9.7	18.8
252.7	0.048	469.4	265.3	67.2	37.9	124.0	17.2	15.5	8.6	18.9
261.7	0.049	482.1	268.1	69.0	38.3	126.1	18.3	15.1	7.7	18.9
281.0	0.049	476.7	261.8	68.1	37.4	130.5	18.3	15.6	7.8	19.3
301.7	0.049	471.3	255.6	67.2	36.5	135.1	18.3	16.1	7.9	19.6
320.8	0.050	481.0	253.4	68.7	36.2	142.4	17.6	16.3	7.8	21.0
340.9	0.050	491.0	251.3	70.2	35.9	150.0	17.0	16.4	7.7	22.4
366.6	0.050	520.8	249.2	74.4	35.6	142.3	24.5	14.5	6.9	19.5
394.2	0.050	552.4	247.1	78.9	35.3	135.0	24.7	12.7	6.2	17.0
418.2	0.050	579.1	251.3	82.8	35.9	139.5	36.6	12.3	6.0	16.8
443.6	0.051	607.2	255.5	86.8	36.5	144.2	38.6	11.9	5.7	16.6
470.6	0.051	654.6	261.8	93.6	37.4	155.6	40.7	11.7	5.4	16.3
499.2	0.052	705.6	268.8	100.9	38.4	168.0	42.9	11.6	5.1	15.9
539.2	0.052	693.1	273.0	99.1	39.0	177.4	40.1	12.2	5.5	16.4
582.4	0.053	680.8	277.2	97.3	39.6	187.3	37.4	13.0	6.0	17.0
620.4	0.053	689.1	288.4	98.4	41.2	196.0	36.1	13.2	6.1	17.4
660.8	0.054	697.5	300.3	99.6	42.9	205.1	34.9	13.4	6.2	17.8
682.3	0.054	683.4	298.9	97.7	42.7	209.7	33.8	13.7	6.1	18.0
704.4	0.055	669.6	297.5	95.8	42.5	214.5	32.8	14.0	6.1	18.1
743.6	0.055	662.5	296.8	94.8	42.4	212.1	32.7	13.8	6.1	18.1
784.9	0.055	655.5	296.8	93.8	42.4	209.7	32.6	13.5	5.9	18.2
823.9	0.055	677.5	304.5	96.9	43.5	221.9	32.8	13.5	5.9	18.3
864.9	0.056	700.3	312.9	100.2	44.7	234.8	33.0	13.6	5.9	18.4
893.6	0.056	721.8	322.0	104.1	46.0	243.4	33.0	13.3	6.1	19.3
923.3	0.057	744.0	331.1	108.1	47.3	252.3	32.9	13.0	6.2	20.2
921.4	0.057	768.3	345.1	110.8	49.3	265.7	32.0	13.2	6.3	21.1
919.8	0.057	793.3	359.8	113.5	51.4	279.9	31.2	13.3	6.3	22.1
1021.5	0.058	839.7	368.9	120.0	52.7	293.7	30.0	12.9	6.4	21.1
1134.4	0.058	898.8	378.7	126.8	54.1	308.2	29.1	12.6	6.4	20.1

Total Vehicles With C/Lic '000 (12)	Motorcars With C/Lic. '000 (13)	Non_Cars With C/Lic. '000 (14)	Price Gasoil Ksh/L (15)	Gasoil Per Capita Litres (16)	Gasoil per Firm '000L (17)	Motor Spirit PerH/Hold Litres (18)	Price M.Spirit (19)	15%of Total Jetfuel M.Litres (20)	Price Jetfuel Ksh/L (21)	Movements in Main airports '000 (22)
94.6	42.9	51.7	0.75	12.5	610	124.4	0.92	12.6	0.78	28.5
96.4	43.6	52.8	0.76	12.6	609	122.5	0.92	14.1	0.78	30.2
98.3	44.4	53.9	0.77	12.7	609	120.6	0.98	15.7	0.83	32.0
100.6	45.2	55.5	0.77	13.3	659	121.9	0.98	19.1	0.83	31.9
103.2	46.0	57.2	0.77	13.9	713	123.2	1.02	23.1	0.86	31.8
106.3	47.0	59.3	0.77	14.4	713	126.2	1.02	23.1	0.83	32.1
109.4	48.0	61.4	0.77	14.9	713	129.3	1.03	23.1	0.87	32.5
111.3	48.6	62.7	0.77	16.1	775	132.0	1.03	24.7	0.87	29.5
113.3	49.2	64.1	0.77	17.3	842	134.8	1.03	26.5	0.87	26.7
118.7	51.3	67.4	0.77	17.0	802	135.6	1.03	28.4	0.87	31.0
124.3	53.5	70.8	0.77	16.8	763	136.4	1.03	30.5	0.87	36.1
130.6	55.9	74.7	0.76	16.8	722	141.6	1.03	32.1	0.87	39.1
137.3	58.5	78.8	0.75	16.9	683	147.0	1.03	33.7	0.87	42.3
143.4	61.0	92.4	0.78	19.0	764	154.6	1.06	35.0	0.92	42.3
149.8	63.6	86.2	0.82	21.3	854	162.6	1.09	36.4	0.92	43.2
154.8	65.2	89.3	0.82	22.1	787	165.8	1.09	39.0	0.92	43.4
160.0	57.5	92.5	0.82	23.0	727	169.0	1.09	41.7	0.92	44.5
162.0	69.1	92.9	0.83	23.6	783	174.6	1.18	46.3	0.92	45.7
164.0	70.7	93.3	0.84	24.2	843	180.4	1.28	51.3	1.09	46.9
173.8	74.4	99.4	0.99	23.5	803	173.8	1.57	49.5	1.33	49.1
184.1	78.3	105.8	1.16	22.9	764	167.5	1.92	47.8	1.63	51.3
191.7	81.0	110.8	1.26	22.7	746	168.4	2.18	52.0	1.85	54.4
199.7	83.7	116.0	1.36	22.6	728	169.3	2.47	56.6	2.09	57.6
201.5	91.4	109.6	2.41	23.1	761	164.5	2.51	55.6	2.13	57.8
203.4	99.9	103.5	1.77	23.7	796	159.8	2.56	54.6	2.17	58.1
208.8	102.0	106.8	1.85	24.3	792	155.3	2.65	53.6	2.25	54.6
214.4	104.2	110.2	1.94	24.9	798	150.9	2.75	52.7	2.33	51.4
219.8	106.6	113.2	2.06	24.3	802	152.5	2.81	52.4	2.39	50.6
225.4	109.1	116.3	2.18	23.9	817	154.2	2.87	52.1	2.45	49.9
228.7	109.7	118.9	2.29	25.1	885	157.1	3.16	54.7	2.69	47.6
232.0	110.4	121.6	2.41	26.4	958	160.0	3.48	57.4	2.95	45.5
236.0	112.0	124.2	2.79	28.0	1012	156.5	4.06	58.9	3.44	44.9
240.4	113.6	126.8	3.23	29.7	1070	153.0	4.73	60.5	4.01	44.3
243.2	113.9	129.3	3.79	27.9	980	149.5	5.46	60.1	4.63	45.4
246.1	114.2	131.9	4.44	26.3	897	146.1	6.30	59.8	5.34	46.5
247.6	114.7	132.9	4.93	25.7	842	136.2	6.78	54.1	5.75	47.7
249.2	115.3	133.9	5.48	25.2	791	127.0	7.30	49.0	6.19	48.9
250.0	116.1	133.9	5.48	25.2	797	121.5	7.53	46.3	6.49	48.1
250.9	116.9	134.0	5.48	25.2	804	116.2	7.76	43.5	6.58	47.3
258.6	119.6	139.1	5.71	25.7	829	114.3	8.04	44.3	6.82	47.9
266.6	122.3	144.3	5.94	26.2	855	112.4	8.34	45.1	7.07	48.4
269.0	125.4	143.6	5.94	24.6	885	104.1	8.34	42.0	7.11	49.0
271.5	128.6	142.9	5.94	23.1	916	97.0	8.34	39.2	7.15	49.7

Lighting Kerosene perH/Hold m.Litres (23)	Price Kerosene Ksh/L (24)	Price LPG Ksh/L (25)	LPG Per H/Hold Litres (26)	Price Heavy Dies.oil Ksh/L (27)	Heavy Dies.oil per Firm '000L (28)	Fuel oil per Firm M.Litres (29)	Price Fuel oil Ksh/L (30)	Price of Coal Ksh/Kg (31)	Price of Charcoal Ksh/Bag (32)
31.2	0.84			0.40	142.2	2.4	0.30	0.12	3.69
31.9	0.84			0.40	145.2	2.2	0.30	0.11	3.78
32.7	0.84			0.40	148.2	2.1	0.30	0.10	3.87
32.6	0.84			0.40	158.6	2.2	0.30	0.10	3.92
32.5	0.84			0.40	169.8	2.3	0.30	0.11	3.95
34.9	0.84			0.40	163.1	2.2	0.30	0.10	5.46
37.4	0.84			0.40	156.7	2.2	0.30	0.10	7.55
38.5	0.84			0.40	162.5	2.1	0.30	0.10	8.01
39.6	0.92	1.64	5.8	0.40	168.6	2.0	0.30	0.10	8.65
36.1	0.91	1.62	6.3	0.40	160.5	1.7	0.30	0.11	8.80
32.9	0.90	1.60	6.9	0.40	152.7	1.5	0.30	0.13	8.95
34.2	0.95	1.69	7.4	0.40	152.4	1.5	0.30	0.11	9.00
35.6	1.00	1.78	8.0	0.39	152.2	1.4	0.31	0.09	9.05
34.7	1.08	1.80	8.5	0.39	157.0	1.4	0.32	0.10	9.44
33.9	1.16	2.07	9.1	0.34	161.7	1.4	0.34	0.11	9.85
36.1	1.20	2.16	9.8	0.34	145.9	1.3	0.34	0.12	10.32
38.5	1.24	2.25	10.5	0.34	131.1	1.2	0.34	0.13	10.82
37.7	1.21	2.25	8.4	0.36	141.6	1.2	0.36	0.12	11.10
36.9	1.19	2.25	6.8	0.38	152.6	1.2	0.38	0.12	11.38
36.6	1.21	2.25	6.7	0.52	136.5	1.1	0.49	0.13	12.08
36.3	1.24	2.25	6.6	0.72	122.1	1.1	0.63	0.14	12.82
36.5	1.27	2.73	6.9	0.80	106.3	1.1	0.69	0.18	13.71
36.8	1.30	3.32	7.2	0.90	92.6	1.1	0.75	0.23	14.67
36.6	1.40	3.32	7.3	1.00	108.3	1.2	0.81	0.24	14.86
36.5	1.50	3.32	7.4	1.11	126.7	1.3	0.87	0.26	15.05
36.3	1.54	3.32	7.6	1.13	103.3	1.3	0.91	0.27	15.76
36.2	1.58	3.32	7.8	1.16	84.2	1.3	0.95	0.29	16.50
38.5	1.58	3.32	7.8	1.34	80.2	1.2	1.05	0.38	17.27
40.9	1.58	3.32	7.9	1.54	76.3	1.2	1.15	0.50	18.08
44.0	1.67	3.57	8.5	1.62	80.6	1.2	1.19	0.74	21.15
47.3	1.76	3.84	9.1	1.70	85.1	1.2	1.23	1.11	24.74
45.4	2.01	4.03	9.1	1.97	95.9	1.2	1.40	1.29	26.32
43.6	2.30	4.25	9.2	2.28	108.1	1.2	1.59	1.51	28.00
43.5	2.59	4.70	9.0	2.67	88.5	1.1	1.82	1.94	32.40
43.4	2.92	5.20	8.9	3.13	72.4	1.0	2.08	0.59	37.15
41.0	2.86	5.20	8.7	3.13	63.5	1.0	2.11	0.59	44.39
38.8	3.80	5.20	8.5	3.13	55.6	0.9	2.14	0.59	53.03
37.9	3.84	5.20	8.7	3.13	51.7	0.8	2.14	0.97	54.49
37.1	3.90	5.20	9.0	3.13	48.0	0.7	2.14	1.59	56.00
36.3	4.13	6.00	9.2	3.28	49.9	0.8	2.24	1.18	56.00
35.5	4.37	6.83	9.4	3.43	51.9	0.9	2.35	0.87	56.00
34.2	4.37	6.83	9.4	3.43	51.6	0.9	2.35	0.97	57.67
32.9	4.37	6.83	9.4	3.43	51.3	0.8	2.35	0.87	60.00

Coal per Fire '000Kg (33)	Total commer. Energy '000Toe (34)	Dom.Elect Sales per H/Hold kWhr (35)	Esti. Price Dom.Elect Cts/KWhr (36)	Off_Peak per Capita M.KWhr (37)	Price Off_Peak Cts/KWhr (38)	Price of Indu.Sales Cts/KWhr (39)	Indust. Sales Per Fire M.KWhr (40)
185.6	895.6	74.80	12.47	7.8	11.00	9.30	0.98
228.4	900.6	72.99	12.49	7.8	11.00	9.35	0.92
281.1	905.6	71.22	12.52	7.9	11.00	9.40	0.85
270.8	941.5	72.53	12.51	7.8	11.00	9.35	0.91
260.8	978.9	73.86	12.50	7.7	11.00	9.30	0.98
250.7	1010.7	73.51	12.49	7.8	11.00	9.93	0.98
240.9	1043.5	73.17	12.46	7.9	11.00	10.60	0.96
218.7	1055.4	73.59	13.13	8.0	11.00	8.00	1.08
198.6	1067.4	74.01	13.83	8.1	12.00	6.00	1.18
163.7	1055.7	72.04	13.90	8.0	12.00	6.00	1.20
134.9	1044.1	70.12	13.98	8.0	12.00	6.00	1.23
200.7	1110.3	71.26	14.01	8.3	12.00	6.00	1.23
298.6	1190.7	72.41	14.04	8.6	12.00	6.00	1.24
291.3	1246.6	73.30	14.00	8.8	12.00	6.00	1.32
284.2	1316.2	74.20	13.97	9.0	12.00	6.00	1.41
173.6	1366.3	75.51	13.98	9.4	12.00	6.50	1.30
106.0	1418.3	76.84	14.00	9.8	13.00	7.00	1.20
145.2	1473.4	77.73	14.50	9.7	13.00	6.90	1.31
198.9	1530.6	78.64	15.02	9.7	13.00	6.80	1.42
184.4	1523.0	80.05	15.00	9.5	13.00	7.56	1.42
171.0	1515.5	81.48	14.99	9.3	13.00	8.40	1.43
137.0	1557.2	84.01	14.99	9.6	15.34	9.90	1.40
109.8	1600.1	86.62	14.99	10.0	18.10	11.70	1.37
128.1	1681.7	86.07	17.31	9.6	19.63	13.30	1.44
149.4	1767.8	85.53	20.00	9.3	21.30	15.10	1.52
142.5	1808.8	89.40	21.89	8.5	21.20	17.80	1.68
136.0	1850.8	93.45	23.97	7.7	21.10	20.90	1.85
124.5	1847.4	96.45	35.45	7.7	21.20	26.42	2.02
114.9	1844.1	99.59	52.42	7.8	21.30	33.40	2.20
65.2	1845.6	132.91	53.17	7.9	21.20	35.48	2.15
37.8	1847.2	177.47	53.93	8.0	21.10	37.70	2.10
38.2	1962.6	176.99	52.51	7.5	21.64	37.70	2.11
38.4	2085.3	176.51	51.13	7.0	22.20	37.70	2.13
84.8	2036.7	180.65	52.35	7.0	22.00	37.40	2.12
187.2	1989.3	184.88	53.60	7.1	21.80	37.20	2.11
189.6	1959.2	184.17	53.50	6.8	22.15	37.40	2.08
192.0	1929.6	183.46	53.39	6.6	22.50	37.70	2.05
112.5	1871.4	186.24	61.65	6.3	31.00	42.64	2.04
65.9	1815.0	189.06	71.18	6.1	42.71	48.22	2.04
99.8	1922.0	191.13	76.24	6.2	49.27	53.64	2.09
515.0	2035.4	193.23	81.65	6.2	56.83	59.66	2.14
152.0	2038.7	195.33	84.83	5.8	60.26	62.75	2.27
153.1	2042.1	197.46	88.13	5.5	65.90	56.01	2.40

Coal per Fire '000Kg (33)	Total commer. Energy '000Toe (34)	Dom.Elect Sales per H/Hold kWhr (35)	Esti. Price Dom.Elect Cts/KWhr (36)	Off_Peak per Capita M.KWhr (37)	Price Off_Peak Cts/KWhr (38)	Price of Indu.Sales Cts/KWhr (39)	Indust. Sales per Fire M.KWhr (40)
185.6	895.6	74.80	12.47	7.8	11.00	9.30	0.98
228.4	900.6	72.99	12.49	7.8	11.00	9.35	0.92
281.1	905.6	71.22	12.52	7.9	11.00	9.40	0.85
270.8	941.5	72.53	12.51	7.8	11.00	9.35	0.91
260.8	978.9	73.86	12.50	7.7	11.00	9.30	0.98
250.7	1010.7	73.51	12.49	7.8	11.00	9.93	0.98
240.9	1043.5	73.17	12.46	7.9	11.00	10.60	0.98
218.7	1055.4	73.59	13.13	8.0	11.00	8.00	1.08
198.6	1067.4	74.01	13.83	8.1	12.00	6.00	1.18
163.7	1055.7	72.04	13.90	8.0	12.00	6.00	1.20
134.9	1044.1	70.12	13.98	8.0	12.00	6.00	1.23
200.7	1110.3	71.26	14.01	8.3	12.00	6.00	1.23
298.6	1190.7	72.41	14.04	8.6	12.00	6.00	1.24
291.3	1246.6	73.30	14.00	8.8	12.00	6.00	1.32
284.2	1316.2	74.20	13.97	9.0	12.00	6.00	1.41
173.6	1366.3	75.51	13.98	9.4	12.00	6.50	1.30
106.0	1418.3	76.84	14.00	9.8	13.00	7.00	1.20
145.2	1473.4	77.73	14.50	9.7	13.00	6.90	1.31
198.9	1530.6	78.64	15.02	9.7	13.00	6.80	1.42
184.4	1523.0	80.05	15.00	9.5	13.00	7.56	1.42
171.0	1515.5	81.48	14.99	9.3	13.00	8.40	1.43
137.0	1557.2	84.01	14.99	9.6	15.34	9.90	1.40
109.8	1600.1	86.62	14.99	10.0	18.10	11.70	1.37
128.1	1681.7	86.07	17.31	9.6	19.63	13.30	1.44
149.4	1767.8	85.53	20.00	9.3	21.30	15.10	1.52
142.5	1808.8	89.40	21.89	8.5	21.20	17.80	1.68
136.0	1850.8	93.45	23.97	7.7	21.10	20.90	1.85
124.5	1847.4	96.45	35.45	7.7	21.20	26.42	2.02
114.9	1844.1	99.59	52.42	7.8	21.30	33.40	2.20
65.2	1845.6	132.91	53.17	7.9	21.20	35.48	2.15
37.8	1847.2	177.47	53.93	8.0	21.10	37.70	2.10
38.2	1962.6	176.99	52.51	7.5	21.64	37.70	2.11
38.4	2085.3	176.51	51.13	7.0	22.20	37.70	2.13
84.8	2036.7	180.65	52.35	7.0	22.00	37.40	2.12
197.2	1989.3	184.88	53.60	7.1	21.80	37.20	2.11
189.6	1959.2	184.17	53.50	6.8	22.15	37.40	2.08
192.0	1929.6	183.46	53.39	6.6	22.50	37.70	2.05
112.5	1871.4	186.24	61.65	6.3	31.00	42.64	2.04
65.9	1815.0	189.06	71.18	6.1	42.71	48.22	2.04
99.8	1922.0	191.13	76.24	6.2	49.27	53.64	2.09
515.0	2035.4	193.23	81.65	6.2	56.83	59.66	2.14
152.0	2038.7	195.33	84.83	5.8	60.26	62.75	2.27
153.1	2042.1	197.46	88.13	5.5	65.90	66.01	2.40

BIBLIOGRAPHY

Adelman, M.A. (1984) "The Future of Oil Supply and Demand." Hawdon, D. (ed.), The Energy Crisis: Ten Years After. London: Croom Helm.

Al-Ali, H.M. (1979) "Input-Output Analysis of Energy Requirements." Energy Economics Vol. 1, No. 4.

Amann, H. (1969) Energy Supply and Economic Development in East Africa. Munchen: Welt Forum Verlag.

Amuzegar, J. (1986). "The Oil Price Turmoil" Finance and Development Vol. 21, No. 2.

Anderson, D. and Fishwick, R. (1984) Fuelwood Consumption and Deforestation in African Countries. World Bank Staff Working Paper No. 704. Washington D.C.: World Bank.

Atkinson, S. (1978) "Responsiveness to Time-of-Day and Electricity Pricing." Journal of Econometrics Vol. 9.

Balestra, P. and Nerlove, M. (1966) "Polling Cross Section and Time Series in the Estimation of a Dynamic Model: The Demand for Natural Gas." Econometrica Vol. 34, No. 3.

Balestra, P. (1967) The Demand for Natural Gas in the United States. A Dynamic Approach for the Residential and Commercial Markets. Amsterdam: North-Holland.

Baron, D.P. and De Bondt, R. (1979) "Fuel Adjustment Mechanisms and Economic Efficiency." Journal of Industrial Economics Vol. 27, No. 3.

Baumal, W.J. (1977) Economic Theory and Economic Analysis. 4th Ed., New Jersey: Printice-Hall.

Baxter, R.E. and Rees, R. (1968) "An Analysis of the Industrial Demand for Electricity." Economic Journal Vol. 78, No. 2.

Beijer Institute and Scandinavian Institute for African Studies (1983) Energy and Development in Kenya: Opportunities and Constraints. Energy, Environment and Development in Africa, No. 1. Sweden: Uddevalla.

Beijer Institute (1982) Energy Development in Kenya: Problems and Opportunities. Nairobi. Mimeo.

Beijer Institute and Scandinavian Institute for African Studies (1984) Wood Energy and Households: Perspectives for Rural Kenya. Energy, Environment and Development in Africa, No. 6. Sweden: Uddevalla.

Beirlein, J.G. Dunn, W.J. and McConnon, J.C. JR (1981) "The Demand for Electricity and Natural Gas in the Northern United States." Review of Economics and Statistics Vol. 63, No. 3.

Berndt, E.R. and Morrison, C. (1980) "Energy, Capital and Productivity." Dunkerley, J. (ed.) International Energy Strategies. Proceedings of the 1979 IAEE/RFF Conference. Cambridge, Massachusetts: Oelgeschlager Gunn and Hain.

Berndt, E.R. and Wood, D.O. (1979) "Engineering and Econometric Interpretation of the Energy Capital Complementarity." American Economic Review Vol. 59, No. 3.

Berndt, E.R. and Wood, D.O (1975) "Technology, Prices and the Derived Demand for Energy." Review of Economics and Statistics Vol. 57, No. 3.

Berndt, E.R., Fuss, M.A. and Waverman, L. (1978) "Factor Markets in General Disequilibrium: Dynamic Models of the Industrial Demand for Energy." Workshop on Energy Supply and Demand. Paris: International Energy Agency.

Bjerkholt, O. and Olsen, O. (1984) "Uncertainty in Hydroelectric Power Supply." Energy Economics Vol. 6, No. 3.

Bohi, D.R. (1982) Price Elasticities of Demand for Energy: Evaluating the Estimates. Research Project 1220-1 Resources for the Future. Washington D.C.

Cameron, T.A. and Schwartz, S.L. (1979) "Sectoral Energy Demand in Canadian Manufacturing Industries." Energy Economics Vol. 1, No. 2.

Carey, M. (1978) A Long Term Programming Model of the U.K. Energy Sector B 45, 1978. University Forecasting Methodology. Energy Paper No. 29, HMSO.

Cherniavsky, E.A. (1974) Brookhaven Energy Systems Optimization Model. Brookhaven National Laboratory. Tropical Report No. BNC 15569. Upton: Associated Universities Inc.

Chiang, A.C. (1967) Fundamental Methods of Mathematical Economics. Tokyo: Kogakusha.

Christensen, R.L., Jorgensen, D.W. and Lau, L.J. (1975) "Transcendental Logarithmic Utility Functions." American Economic Review Vol. 63, No. 3.

Christensen, R.L., Jorgensen, D.W. and Lau, L.J. (1973) "Transcendental Logarithmic Production Frontiers." Review of Economics and Statistics Vol. 55, No. 1.

Cooper, B. (ed.) (1979) OPEC OIl Report. The Petroleum Economist 2nd edition, London.

Dahl, C.A. (1979) "Consumer Adjustments to a Gasoline Tax." Review of Economics and Statistics Vol. 61, No. 3.

Dartmouth Systems Dynamic Group (1977) Fossil 1. An Introduction to the Model. Thayer School of Engineering, Dartmouth College, Hanover. Mimeo.

Day, R.H. and Tabb, W.K. (1972) A Dynamic Macroeconomic Model of the U.S. Coal Mining Industry. Social Science Research Institute, Research Paper, University of Wisconsin, Madison.

Deanne, J. (1981) Energy Pricing in Developing Countries: Lessons from the Egypt Study. Energy Department, World Bank. Mimeo.

Deese, D.A. and Nye J.S. (1981). Energy and Security. A Report of Harvard's Energy and Security Research Project. Cambridge, Massachusetts: Ballinger.

Desai A.V. (1980) "Development and Energy Consumption" In: Pachauri, R.K. (ed.), International Energy Studies. New Delhi: Wiley Eastern.

Dewees, D.N. Hyndman, R.M. and Wareman, L. (1975) "Gasoline Demand in Canada 1956-73." Energy Policy Vol. 3.

Dobbs, I.M. (1982) "Combined Heat and Power Economics." Energy Economics Vol. 4, No. 4.

Dunkerley, J. (1980) "Energy Output Relationships: Implications for Energy Conservation." In: Dunkerley, J. (ed.), International Energy Strategies. Proceedings of the 1979 International Association of Energy Economists/Resources for the Future Conference. Oelgeschlager, Gunn and Hain.

Dunkerley, J. (1980) "Domestic Energy Consumption by the Poor in Developing Countries." Pachauri, R.K. (ed.), International Energy Studies. New Delhi: Wiley Eastern.

Dunkerley, J. and Steinfied, A. (1980) "Adjustment to Higher Oil Prices in Oil Importing Developing Countries." Journal of Energy and Development Vol. 5, Spring.

Durbin, J. (1969) "Tests for Serial Correlation in Regression Analysis Based on the Periodogram of Least Squares Residuals." Biometrika Vol. 56, No. 1.

Eden, R., Posner, M., Bending, R., Crouch, E. and Stanislaw, J. (1981) Energy Economics - Growth, Resources and Policies. Cambridge, U.K.: Cambridge University Press.

El Serafy, S. (1979) The Oil Price Revolution of 1973-74. World Bank Reprint Series No. 119. Washington D.C.: World Bank.

Field, B. and Grebenstein, C. (1980) "Capital Energy Substitution in U.S. Manufacturing." Review of Economics and Statistics Vol. 62, No. 2.

Fisher, F.M. and Kaysen, C. (1962) Demand for Electricity in the United States. A Study of Econometrics. Amsterdam: North-Holland Publishing Company.

Foley, G. (1984) "Outside the Oil Economy - Rural Energy in Developing Countries." Shaw, T.L., Lennard, D.E. and Jones P.M.S. (eds.) Policy and Development of Energy Resources. John Wiley and Sons.

Franssen, H. (1984) "Structural Change in the Oil Market." Energy Policy Vol. 12, Number 1.

Friedlaender, A.F. and Spady, R.H. (1980) "A Derived Demand Function for Freight Transportation." Review of Economics and Statistics Vol. 62, No. 3.

Garvey, G. (1972) Energy Economy and Environment. A Framework for Environmental Policy. London: Norton and Company.

Gecau, J.K. (1980) "The Role of Electricity in the Developing of Energy Policy for Kenya." United Nations Environmental Programme: Energy and Environment in East Africa. Proceedings of an International Workshop, Nairobi.

Githinji, P.M. (1978) Kenya's Energy Needs, Possible Supplies and Impact on Environment. An input to the Government of Kenya/UNEP/UNDP Project on Environment and Development, Nairobi, Mimeo.

Granger, C., Engle, R., Ramanathan, R. and Anderson, A. (1970) "Residential Load Curves and Time-of-Day Pricing." Journal of Econometrics Vol. 9.

Greenhut, M.L. and Ohta, H. (1979) "Vertical Integration of Successive Oligopolies." American Economic Review Vol. 69, No. 1.

Griffin, J.M. and Gregory, P.R. (1976) "An Inter Country Translog Model of Energy Substitution Responses." American Economic Review Vol. 66, No. 4.

Harlvorsen, R. (1975) "Residential Demand for Electric Energy." Review of Economics and Statistics Vol. 57.

Hartshorn, J.E. (1980) "From Multinational to National Oil: the Structural Changes." Journal of Energy and Development Vol. 5, Spring.

Hawdon, D. and Tomlinson, M. (1982) Energy Models in USA and U.K. Surrey Energy Economic Centre. Discussion Paper No. 8.

Herman, B. (1978) "A Case of Multinational Oligopoly in Poor Countries: Oil Refinery Investment in East Africa. Kaplinsky, R. (ed.) Readings in Multinational Corporations in Kenya. Nairobi: Oxford University Press.

Hourcade, J.C. (1981) "Energy Development Styles and Capital Requirement in Third World Countries." Development Vol. 2.

House, J.M. and Killick, A. (1980) "Future Development Possibilities for Kenya and their Energy Implications." UNEP Energy and Environment in East Africa. Proceedings of an International Workshop, Nairobi.

Hudson, E.A. and Jorgensen, D.W. (1976) "Tax Policy and Energy Conservation." Jorgensen, D.W. (ed.) Econometric Studies of U.S. Energy Policy. Amsterdam: North Holland.

Intrilligator, M.D. (1978) Econometric Models, Techniques and Application. Amsterdam: North-Holland.

Johnston, J. (1972) Econometric Methods. Second Edition. Tokyo: Kogakusha.

Jones, M.J. (1983) Industrial Energy Use in Kenya. Results and Analysis of a Survey of Major Industries. Kenya Renewable Energy Development Project. Energy Development International, Nairobi.

Jorgensen, D.W. (ed.) (1976) Econometric Studies of the U.S. Energy Policies. Amsterdam: North-Holland.

Jorgensen, D.W. (1977) "Consumer Demand for Energy." Nordhaus, D. (ed.) International Studies of the Demand for Energy. Amsterdam: North-Holland.

Kelejian, H.H. and Oates, W.E. (1981) Introduction to Econometrics. Principles and Applications. Second Edition. New York: Harper and Row.

Kennedy, M. (1976) "A World Oil Model." Jorgensen, D.W. (ed.). Econometric Studies on the U.S.A. Energy Policies. Amsterdam: North-Holland.

Kennedy, M. (1974) "An Econometric Model of the World Oil Market." Bell Journal of Economics and Management Science Vol. 5, No. 2.

Kimuyu, P.K. (1985) Oil Industry Investment Under a Changing International Oil Industry: Some Observations on Kenya. Paper presented to the Kenyan Economic Association, Panafric Hotel, Nairobi. 22nd November.

Kimuyu, P.K. (1984) Demand for Fossil Fuels in Kenya. Unpublished M.Sc. Dissertation. University of Surrey, England.

Kouris, G. (1976) The Determinants of Energy Demand in the EEC Area. University of Surrey, U.K. Mimeo.

Kristoferson, L. (1980) "Global Energy Research: Implications for Sweden and Kenya." UNEP: Energy and Environment in East Africa. Proceedings of an International Workshop, Nairobi.

Labys, W.C. (1981) "Measuring the Validity and Performance of Energy Models." Energy Economics. Vol. 3, No. 3.

Lewis, J.R. and Schmalensee, R. (1980) "On Oligopolistic Markets for Non-Renewable Natural Resources." Quarterly Journal of Economics Vol. 55.

Lin, A., Botsas, E.N. and Monroe, S.E. (1985) "State Gasoline Consumption in the U.S.A." Energy Economics Vol. 7, No. 1.

Marquand, C.S. and Githinji, P.M. (1980) "Energy Resources in Kenya and their Environmental Impact." In: UNEP, Energy and Environment in East Africa. Proceedings of an International Workshop, Nairobi. Energy Report Series Number ERS-3-80.

Meadows, D.H., Meadows, D.L., Randers, J. and Behrens, W.W. (1972). The Limits to Growth. A Report for the Club of Rome's Project on the Predicament of Mankind. London: Pan Books.

Meier, P.M. (1986) Energy Planning in Developing Countries. An Introduction to Analytical Methods. Boulder: Westview Press.

Mork, K.A. (ed.) (1981) Energy Prices Inflation and Economic Activity. Cambridge, Massachusetts: Ballinger.

Munasinghe, M. (1983) "Third World Energy Policies: Demand Management and Conservation." Energy Policy Vol. 11, No. 1.

Munasinghe, M. (1981) "Optimal Electricity Supply Reliability and System Planning." Energy Economics Vol. 3, No. 3.

Munasinghe, M. (1980) "A New Approach to Power System Planning." World Bank Reprint, series No. 147, Washington D.C.

Mureithi, L.P., Kimuyu, P.K. and Ikiara, G.K. (1982) The Effects of Higher Energy Costs on the Balance of Payments, Employment Technology Choice and Real Incomes in Kenya. World Employment Programme Research. Paper No. WEP 2-22 WP.106. Geneva: ILO.

Myers, N. (1980) "Bio-Energy for Kenya: Some Technical Possibilities." UNEP: Energy and Environment in East Africa. Proceedings of an International Workshop, Nairobi.

Naill, R.F. (1977) Managing the Energy Transition: A Systems Dynamic Search for Alternatives to Oil and Gas. Cambridge, Massachusetts: Ballinger.

National Energy Assessment Centre (1980) Some Perspectives on Oil Availability for the non-OPEC LDCs - A Research Paper. Mimeo.

Ndobi, J.T. and Bhogal, P.S. (1980) "Prospects for Geothermal Energy in Kenya" UNEP. Energy and Environment in East Africa. Proceedings of an International Workshop, Nairobi. Energy Report series No. ERS-3-80, pp. 259-266.

Nguyen, J.H. (1984) "On Energy Coefficients and Ratios." Energy Economics Vol. 6, No. 2.

Nijkamp, P. (1977) Theory and Application of Environmental Economics. Amsterdam: North-Holland.

Nimtz, G. (1980) "Energy From Space." Universita's - A German Review of Arts and Sciences. Wissencheftlinche verlagsgesellschaft M.B.H. Sturtgat, Quarterly English Language Edition Vol. 22, November.

Nordhaus, W.D. (ed.) (1977) International Studies of the Demand for Energy. Amsterdam: North-Holland.

Odell, P.R. (1984) "Outlook for the International Oil Markets and Options for OPEC." Energy Policy Vol. 12, No. 1.

Odingo, R.S. (1980) "The Development of Hydro-Electric Power Resources in East Africa with Special Reference to Kenya." UNEP: Energy and Environment in East Africa. Proceedings of an International Workshop, Nairobi.

Ohta, M. (1975) "Production Technologies of the US Boiler and Turbo-Generator Industries and Hedonic Price Indices for Their Products: A Cost Function Approach." Journal of Political Economy Vol. 83, No. 1.

Okech, B.A. (1987) Coal Supply Situation: Availability for Substitution in the Kenyan Economy. Institute for Development Studies, University of Nairobi, Working Paper No. 454.

Okech, B.A. (1986) Kenya's National Energy Policy Overview For the Public Law Institute. Mimeo.

Okech, B.A. (1985) Social, Economic, Cultural and Ecological Consequences of New Technologies for Energy Production and Utilization in Kenya. Paris: SHS-85/CONF.610/6.

Onyango, F.N. and Beba, A. (1980) "An Investigation of Solar Energy Distribution in East Africa: The Case of Kenya." UNEP: Energy and Environment in East Africa. Proceedings of an International Workshop, Nairobi.

Ozatalay, S., Grubaugh, S. and Long, T.H. (1979) "Energy Substitution and National Energy Policy." American Economic Review Vol. 69, No. 2.

Pachauri, R.K. (1983) "Third World Energy Policies: The Urban-Rural Devide." Energy Policy Vol. 11, No. 3.

Pachauri, R.K. (1980) "Energy and Development - A Third World Perspective." Pachauri, R.K. (ed.). International Energy Studies. New Delhi: Wiley Eastern.

Park, S.H. (1982) "An Input-Output Framework for Analysing Energy Consumption." Energy Economics Vol. 4.

Pearce, D. and Edwards, R. (1984) Energy Policy in a Price-Regulated Economy: A Study of Egypt. Paper presented to a workshop on the Economics of Energy in LDCs. Surrey Energy Economics Centre, September.

Pearce, J. (ed.) (1983) The Third Oil Shock: The Effects of Lower Oil Prices. Chatham House Special Paper, The Royal Institute of International Affairs. London: Routledge and Kegan.

Pearson, P.J.G. and Stevens, P. (1984) Integrated Energy Policies in LDCs: The Relationship Between Traditional and Commercial Energy Sources. Paper presented at the Fifth International Conference of the International Association of Energy Economics. New Delhi.

Pearson, P.J.G. and Stevens, P. (1985) The Economics of Energy in LDCs. A Report on a Workshop. Surrey Energy Economics Centre. Discussion Paper No. 21.

Pearson, P.J.G. (1984) Energy Policy Environment and Income Distribution in Less Developed Countries. An Input-Output Approach. Surrey Energy Economics Centre. Discussion Paper No. 15.

Pindyck, R.S and Rubinfeld, D.L. (1976) Econometric Models and Economic Forecasts. Tokyo: Kogakusha.

Pindyck, R.S. (1979a) The Structure of the World Energy Demand. Cambridge, Massachusetts: The MIT Press.

Pindyck, R.S. (1979b) "The Structure of Energy Markets." Advances in the Economics of Energy and Resources, Volume 1. Cambridge, Massachusetts: Jai Press.

Pindyck, R.S. (1980) "International Comparison of the Residential Demand for Energy." European Economic Review Vol. 13.

Ramsey, J., Rasche, K. and Allen, B. (1975) "An Analysis of the Private and Commercial Demand for Gasoline." Review of Economics and Statistics Vol. 57.

Rao, P. and Miller, R.L. (1971) Applied Econometrics. Belmont, Wadsworth.

Reardon, W.A. (1973) "Input/Output Analysis of the U.S. Energy Consumption." Searl, M.F. (ed.). Energy Modelling. Resources for the Future. Washington D.C.

Reid, R.G. (1984) Standing the Test of Time. Paper presented to the International Association of Energy Economists Conference on the Changing Structure of the World Oil Industry, Surrey Energy Economics Centre, March.

Republic of Kenya (1985) National Energy Policy. Nairobi: Government Printer.

Republic of Kenya (1984) Development Plan, 1984-88. Nairobi: Government Printer.

Republic of Kenya (1980) The Rural/Urban Household Energy Consumption Survey, October-November 1978. Nairobi: Government Printer.

Republic of Kenya (1979) Statistics of Energy and Power, 1969-1977. Nairobi: Government Printer.

Republic of Kenya (1978) Statistics of Energy and Power, 1969-1977. Central Bureau of Statistics, Ministry of Economic Planning and Community Affairs. Nairobi: Government Printer.

Republic of Kenya (1962) The Petroleum Act Chapter 116 Laws of Kenya. Nairobi: Government Printer.

Robinson, M.S. (1982) The Crude Oil Price Spiral of 1978-1980. London: Shell Centre. Mimeo.

Robinson, C. (1984) "The Changing Energy Market: What Can We Learn from the Last Ten Years?" Hawdon, D. (ed.). The Energy Crisis: Ten Years After. London: Croom Helm.

Rovere, E.L.L. (1981) "Brazil: Solutions Beyond Oil." Development No. 2.

Salmond, A. (1986) "Oil Price Decline Will Not Brint the Benefits Many Expect" OPEC Bulletin July/August.

Samouilidis, J.E. and Mitropoulos, C.S. (1984) "Energy and Economic Growth in Industrializing Countries: The Case of Greece." Energy Economics Vol. 6, No. 3.

Samuelson, P.A. (1972) Foundations of Economic Analysis. New York: Atheneum.

Saunders, H.D. (1984) "The Macrodynamics of Energy Shocks, Short-and Long-Run." Energy Economics Vol. 6, No. 1.

Schipper, L. and Meyers, S. (1983) "Energy Conservation in Kenya's Modern Sector. Progress, Potential and Problems." Energy Policy Vol. 11, No. 3.

Schipper, L. and Mbeche, O. (1980) "Energy Demand and Conservation in Kenya." UNEP: Energy and Environment in East Africa. Proceedings of an International Workshop, Nairobi.

Schipper, L. (1980) Energy Demand and Conservation in Kenya: An Initial Appraisal. Presented at the Electric Power Research Institute Workshop on Energy and the Developing Nations. Hoover Institute, Stanford University, March.

Schipper L. (1979) "Another Look at Energy Conservation." Energy Policy Vol. 69, No. 2.

Senga, W.M., House, W.J. and Manundu, M. (1980) Assessment of the Commercial Energy and Supply in Kenya. Institute for Development Studies, University of Nairobi. Consultancy Report No. 3.

Siddayao, C.M. (1986) Energy Demand and Economic Growth. Measurement and Conceptual Issues in Policy Analysis. Boulder: Westview Press.

Siddayao, C.M. (ed.) (1985) Criteria for Energy Pricing Policy. London: Graham and Trotman.

Soedjatmoko (1981) "The Food-Energy Pivot: Turning Point in Development." Development Vol. 2.

Standard Oil Company of California (1983) World Energy Outlook. San Francisco, June.

Stern, M.R., Baurn, C.F. and Greene, M.N. (1979) "Evidence of Structural Change in the Demand for Aggregate US Imports and Exports." Journal of Political Economy Vol. 87, No. 1.

Stevens, P. (1984) A Survey of Structural Changes in the International Oil Industry 1954-84. Paper presented to the Changing Structure of the World Oil Industry's International Energy Economists Conference, Surrey Energy Economics Centre, England. March 1984.

Stone, R. (ed.) (1968) The Demand for Fuels 1948-75: A Sub Model for the British Fuel Economy. A programme for growth (8), Department of Applied Economics, University of Cambridge. Cambridge, U.K: Chapman and Hall.

Sweeney, J.L. (1984) "The Response of Energy Demand to Higher Prices: What Have We Learned?" American Economic Association's Papers and Proceedings on Economic Effects of the Rise in Energy Prices Vol. 72, No. 2.

Taylor, L. (1979) "On Modelling of the Residential Demand for Electricity on Time-of-Day." Journal of Econometrics Vol. 9.

Tempest, P. (ed.) (1981) Internal Energy Options. An Agenda for the 1980s. Selected Papers from leading contributors to the 1980 annual conference of the International Association of Energy Economists. Cambridge, U.K.

Thery, D. (1981) "The Biogas Programme in India and China: An Ecologically Appropriate Technology in Two Highly Contrasting Socio-Economic Settings." Development, No. 19.

Turnovsky, M., Folie, T. and Ulph, A.M. (1982) "Factor Substitutability in Australian Manufacturing with Emphasis on Energy Inputs." The Economic Record Vol. 58, No. 160.

Tzannetis, E.T. (1978) The Demand for Petroleum in the U.K. 1955-73. Unpublished Ph.D. thesis. University of Surrey, England.

U.K. Department of Energy (1978) Energy Forecasting Methodology. London: HMSO.

Ulph, A.M. (1980) "World Energy Models - A Survey and Critique." Energy Economics Vol. 2.

Uri, N.D. (1980) "Stability of the Demand for Refined Petroleum Fuels in the United States." Energy Systems and Policy Vol. 4, No. 3.

Uri, N.D. (1979a) "Price Expectations and the Demand for Electrical Energy." Energy Systems and Policy Vol. 3, No. 1.

Uri, N.D. (1979b) "Energy Substitution in the U.K. 1948-54." Energy Economics Vol. 1, No. 4.

Waverman, L. (1977) "Estimating the Demand for Energy: Heat Without Light." Energy Policy Vol. 5.

Webb, M.G. and Ricketts, M.J. (1980) The Economics of Energy. London: Macmillan Press.

Weekly Review (1985) "Oil Prospecting Work Starts in Earnest" In: Industrial Review. Nairobi.

William, M. and Laumas, P. (1981) "The Relationship between Energy and Non-energy Inputs in India's Manufacturing Industries." Journal of Industrial Economics Vol. 30, No. 2.

Wilson (1979) "The Price of Oil: A Case of Negative Marginal Revenue." Journal of Industrial Economics Vol. 27, No. 1.

Woldeghiorghis, G. (1981) "Energy, Development and Environment: The Case of Ethiopia." Development Vol. 2.

World Bank (1983) Uganda: Issues and Options in the Energy Sector. A joint UNDP/World Bank Energy Sector Assessment Programme. Report No. 4453-UG. Washington D.C.

World Bank (1982) Kenya: Issues and Options in the Energy Sector. Report of the UNDB/World Bank Energy Sector Assessment Programme. Report No. 3800-KE. Washington D.C.

World Bank (1981a) Accelerated Development in Sub-Saharan Africa: An Agenda for Action. Washington D.C.

World Bank (1981b) Energy Pricing and Developing Countries: A Review of Literature. Energy Department's Paper No. 1. Washington D.C.

World Bank (1981c) Mobilizing Renewable Energy Technology in Developing Countries. Strengthening Local Capabilities and Research. Washington D.C.

World Bank (1981d) Energy Prices, Substitution and Optimal Borrowing in the Short-run An Analysis of Adjustment in Oil Importing Developing Countries. Staff Working Paper No. 466. Washinton D.C.

World Bank (1981e) Energy, International Trade and Economic Growth. Staff Working Paper No. 474, Washington D.C.

World Bank (1980a) Energy in the Developing Countries. Washington D.C.

World Bank (1980b) Alcohol Production from Biomass in Developing Countries. Washington D.C.

World Bank (1979) Energy Options and Policy Issues in Developing Countries. Staff Working Paper No. 350, Washington D.C.

Yu, S.H.E. and Hwang, B.K. (1984) "The Relationship Between Energy and GNP. Further Results." Energy Economics Vol. 6, No. 3.