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AN ECONOMETRIC ANALYSIS OF ENERGY UTILIZATION IN THE  
KENYAN MANUFACTURING SECTOR

By

Susan Moraa Onuonga

Department of Economics

Kenyatta University

Onuonga, Susan Moraa  
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analysis of energy*



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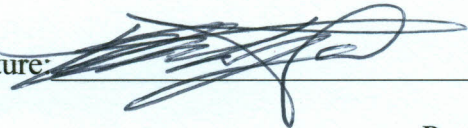
## DECLARATION

This thesis is my original work and has not been presented for award of a degree in any university

Signature:  Date 10/05/2008

Susan M. Onuonga

This thesis has been submitted to the School of Humanities and Social Sciences, Kenyatta University, with our approval as supervisors

Signature:  Date 10-05-2008

Prof. Martin N. Etyang

Signature:  Date 10/05/2008

Prof. Germano Mwabu

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I would like to dedicate this research work to my husband; Peter Okeri, and my children; Lilian, Wycliffe, Dennis and Emma.

and has enabled me to complete this research. I am grateful to many who have supported me in the course of my study. Because I am indebted to acknowledge those who have contributed to the success of this study, I will only mention a few.

I am indebted to my supervisors, Prof. Maitavira M. Mwangi and Prof. Germaine M. Mwangi who devoted their time in giving constructive academic criticisms and suggestions that shaped this study. I also thank Dr. Thomas N. Kibera who served as a third supervisor and a research mentor.

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## ABSTRACT

The overall purpose of this study was to analyze the factors that influence energy utilization in Kenya's manufacturing sector and to determine the extent of substitution possibilities between energy inputs and other non-energy factors of production within the Kenyan manufacturing sector over the 1970- 2005 period. The Kenya manufacturing sector is a major consumer of commercial energy in Kenya. It is the second largest user of petroleum products and the largest user of electricity. There is hardly any evidence that shows that the sector uses biofuels. The analysis of price and non-price variables that affect the use of energy within this sector is necessary for designing policy measures that can lead to energy conservation. Information on the degree of energy substitution is important in predicting the effects of energy shortages on manufactured output and industrial employment. This study used the translog model to analyze total factor demands and inter-fuel substitutions. Estimation was done in two stages. First, the sub-energy model was estimated and an aggregate energy index computed. In the second stage, the total factor cost shares were analyzed using the estimated energy price index as an instrumental variable. Estimation in all stages was done by the use of Maximum Likelihood Method. In divergence from the previous studies in Kenya, time series properties of the data were fully investigated before model estimation was done. The study found that, price of energy, cross price, output, technology, price of capital and unexpected events (droughts, U.S.A's attack on Iraq in 2003, and multiparty elections) influenced the sector's use of energy. The results for inter-fuel model indicated that demand for electricity and oil in the Kenyan manufacturing sector were price inelastic and that oil and electricity are substitutes. The fuel price and the cross price elasticities were found to be small but statistically significant. These results imply that manipulation of the fuel prices alone cannot achieve much in controlling the use of energy in the Kenyan manufacturing sector. Limited substitution possibilities between electricity and oil in this sector were found. Small substitution possibilities between energy and non-energy inputs were also detected. The results for the total factor cost shares showed that demand for energy and labour were price inelastic while that one of capital had a unitary elasticity. The results further showed that energy, labour and capital were substitutes, but the degrees of substitution among the factors were found to be very low, ranging from 0.07 to 0.75. This suggested that costs of production within the sector might rise significantly as a result of the price increase of the inputs, especially of energy.

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## LIST OF ACRONYMS

ADL	Autoregressive Distributed Lag Model
EPP	Emergency Power Producers
ERC	Energy Regulatory Commission
EPZ	Export Processing Zone
GWh	Gigawatt-hour
IPP	Independent Power Producers
KENGEN	Kenya Electricity Generating Company Ltd
KPLC	Kenya Power and Lighting Company
KOE	Kilogrammes of Oil Equivalent
LPG	Liquefied Petroleum Gas
SAP	Structural Adjustment Programmes
UEB	Uganda Electricity Board

## OPERATIONAL DEFINITION OF TERMS

*Biomass Fuels:* refers to organic materials burned or fermented for chemical energy for example, wood, charcoal plants and animal waste

*Commercial Energy:* refers to that energy which is sold in a measurable quantity and standardized value in a market, which includes petroleum and electricity.

*Energy:* source of power, such as electricity

*A Manufacturing firm:* refers to a firm that is engaged in mechanical, physical, or chemical transformation of materials, substances, or components into new products.

*Manufacturing Sector:* Consists of all manufacturing firms that were in operation within Kenya between 1970 and 2005.

*Non-commercial energy:* refers to that energy whose transactions are rarely recorded in the commercial energy statistics, for example, wood fuels and farm waste

*Total energy:* refers to firms' consumption of major types of energy: Oil and oil products, Electricity, coal, and natural gas

# CHAPTER ONE

## INTRODUCTION

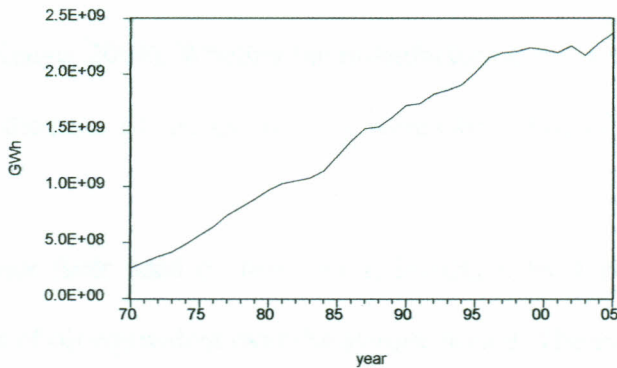
### 1.1 Background to the Study

The manufacturing sector accounts for approximately 10 per cent of Kenya's GDP. The sector's output grew at an average rate of 8 percent per annum between 1970 and 2005. The growth of the sector was associated with greater use of inputs, including all forms of energy. Many changes have taken place in this sector, including the introduction of the Export Processing Zones (EPZ), which brought a lot of changes in the key inputs used by the sector, especially energy. In the Vision 2030, this sector is expected to continue contributing 10 per cent per annum to Kenya's GDP (Republic of Kenya, 2007). Energy, a key determinant of achieving the objective of transforming Kenya into a newly-industrialized middle income country, and yet energy is not adequately covered in the Vision. The manufacturing sector will play a key role in achieving the Vision 2030. For the sector to contribute adequately to this Vision, the factors that influence its energy utilization need to be known so as to improve all energy strategies of the Vision.

The sector is the third largest energy end-user in the economy (Republic of Kenya, 2002a). The importance of the manufacturing sector lies, not so much in the total energy used in this sector, but rather in its reliance on commercial fuels (Beijer, 1984). The sector mainly uses electricity and oil as sources of energy in its production processes, distribution and transport services. The manufacturing sector is the second largest user of petroleum products after the transport sector that leads and the largest user of electricity (Republic of Kenya, 2002a). The use of these two forms of energy has, on average, been increasing the cost of energy and total production cost

within this sector. Energy at the same time has been the major constraint to growth of this sector (Republic of Kenya, 2000a). This is mainly because supply of electricity to this sector is inadequate, costly, and is characterized by frequent rationing.

**Figure 1.1: Trend of electricity usage by the manufacturing sector, 1970-2005**



Source: Republic of Kenya, *Statistical Abstract, Various Issues*. Nairobi: Government Printer.

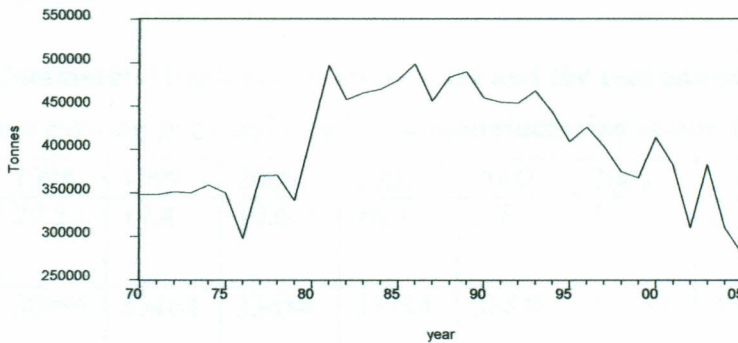
Utilization of electricity in this sector has been steadily growing as shown in Figure 1.1. Consumption of electricity increased by 253 percent, 78 percent, and 29 percent in the years 1970-1980, 1980-1990 and 1990-2000, respectively. Given current trends in industrialization, output and employment, utilization of electricity in this sector is expected to increase in future, with consequent need for expansion in electricity generation.

Tariff reforms have been introduced in the electricity sector to control the use of electricity. For example, retail prices of electricity were adjusted commencing from 1994. In March 1994, tariffs increased by 60percent, in October 1996 and in August 1999, tariffs were increased to slightly above 100percent (Republic of Kenya 1994). In addition to adjustment in tariffs, two formulas were introduced in 1996 to take into account monthly changes in the cost of petroleum

used in power generation and changes in the cost of debt service for both Kenya Electricity Generating (Kengen) Company Ltd and Kenya Power and Lighting Company (KPLC) emanating from fluctuations of the Kenya shilling relative to external currencies in which loans are denominated. All these have implications for the electricity retail prices. However, the effect of changes in tariffs on use of electricity depends on the price elasticity of electricity use. In a recent national energy policy, the government has acknowledged that the consumer tariffs are high (Republic of Kenya, 2004). Whether the manufacturing sector substitutes among the energy forms available, as the price of energy changes, were part of this study.

Oil, one of the major fuels used by this sector, increased by 4 per cent from 34.78 to 36.27 thousands of tonnes of oil equivalent over the sample period. The trend of oil usage by the sector shown in Figure 1.2, suggests that it is difficult to forecast the demand for petroleum fuel.

**Figure 1.2: Trend of oil usage by the manufacturing sector, 1970-2005**



Source: Republic of Kenya, *Economic Survey Various Issues*, Nairobi: Government Printer

There were fluctuations in the use of petroleum fuel between 1970 and the year 2005. Between 1970 and 1980, use of petroleum fuel increased by 20 percent, while it increased by 10 percent and plummeted by 10 per cent in the periods 1980-1990 and 1990-2000, respectively. A big change in oil use by this sector was noted in 1980, when demand increased by 23 per cent. This

may be attributed to drought that led to shortages of rainwater and hence reduction in hydroelectricity generation. The factors responsible for this trend form part of this study.

In the thirty-six years span from 1970 through 2005, the energy sector has experienced several events including the droughts of 1980s, 1999- 2001, the oil crises of 1973, and 1979, the oil glut of 1986, and the energy reforms which were introduced between 1994 and 2000. These reforms include, price decontrols and introduction of other companies in the power sector; notably the independent power producers and the emergency power producers.

Other changes in the manufacturing sector include increase of wage employment by 179 per cent while nominal value added increased by 79 per cent in the period 1970- 2002 (Republic of Kenya, 2004). The effects of these events on energy use in the Kenyan manufacturing sector were part of the study. At the same time, there have been changes in the cost of labour and capital as shown in Table1.1.

**Table1.1: Commercial bank loan interest rates and the real annual average wage earning per employee in the manufacturing sector 1998-2005**

Year	1998	1999	2000	2001	2002	2003	2004	2005
Real interest rate (%)	20.5	19.4	19.6	16.3	3.7	3.7	0.7	2.9
Real wage rate (Kshs.)	30897	33468	33688	35784	36848	37569	35467	38746

Source: Republic of Kenya, *Economic Survey* (1997 to2005). Nairobi: Government Printer

There have been fluctuations in the cost of other inputs used within the manufacturing sector between 1970 and 2005. The cost of obtaining loans from the commercial banks has been fluctuating as shown in table 1.1 affecting capital formation within the Kenyan manufacturing sector. Between 1998 and 2005, real interest rates declined from 20.5 per cent to 2.9 per cent.

On the other hand, the cost of labour has been trending upwards within the sector. Between 1998 and 2005, real earnings per annum per employee increased by 25percent. All these changes reflect changes in the cost of production within the sector. Given the preceding changes, the study investigated the substitution possibilities between energy forms and among energy and other non-energy inputs (capital and labour) within the Kenyan manufacturing sector.

Energy consumption by manufacturing sector has important implications for energy conservation, balance of payments deficit, the country's economic growth, employment, global warming and destruction of the ozone layer.

## **1.2 The Role of Energy in the Economy**

Energy plays a very important role in our everyday life, from sustaining our daily life to fuelling national development. Energy facilitates all human effort. Domestically, energy is used for space heating, cooking, and as a source of light among other uses. In the health sector, there is hardly any service that is offered without the use of commercial energy. All industrial production processes, transportation and distribution services use commercial energy. In the agricultural sector, commercial energy is used for drying agricultural products, transporting of inputs and outputs, tilling land and harvesting among others.

The level and intensity of use of commercial energy are key indicators of a country's development and economic growth (Republic of Kenya, 2004). Countries with low utilization of commercial energy have been observed to register low economic performance. Table 1.2 shows GDP and utilization of commercial energy for selected countries.

**Table 1.2: Per capita GDP relative to per capita commercial energy consumption for selected countries**

	Per capita gross domestic Product (US \$)			Per capita commercial energy use (KOE)		
	1971	1994	2000	1971	1994	2000
Kenya	127	250	360	116	110	514.8
Egypt	211	720	1,490	213	600	728.1
South Africa	719	3,040	3,050	1,993	2,146	2,474.0
Zimbabwe	264	500	440	443	438	807.8
Malaysia	406	3,480	3,390	435	1,699	2,080
South Korea	298	8,260	9,790	507	2,982	4,060.9
Singapore	1,088	22,500	22,890	1,551	8,103	5,560.7
Sub-Saharan Africa	198	460	480	225	237	664.7
High Income Economies	3,066	23,420	26,520	4,407	5,066	5,1089

Source: World Bank (2005).

Kenya's utilization of commercial energy per capita shows a downward trend between 1971 and 1994. This is attributed to weak and sluggish economic performance. This contrasts with the use of commercial energy in countries that have recorded good economic performance such as Egypt and South Africa, both of which are Kenya's trading partners in Eastern and Southern Africa. These two countries registered impressive growth in both energy use and GDP during this period. Kenya's Per capita commercial energy utilization declined by 5 per cent between 1971 and 1994. This decline is attributable to a corresponding declining economic performance.

Between 1974 and 1979, GDP grew at a rate of 5.2 percent per annum on average, however, this growth persistently declined in the subsequent years, averaging 4.1 percent, and 2.5 percent per annum over the periods 1980-89 and 1990-95, respectively. Among the factors that contributed

to this declining economic performance were the oil shocks of the 1970s and 1980s, and pursuit of weak macro-economic and structural adjustment policies.

Generally, Kenya's per capita commercial energy utilization is seen to be the least as compared to other countries. This is attributable to low level of industrialization as the manufacturing sector only contributes 13 percent of GDP, high cost of access to commercial energy, especially electricity; low per capita incomes, high dependence on rain-fed agricultural sector which is the main source of income in the country and limited investment in supply and distribution networks (Republic of Kenya, 2004).

Given that the level and intensity of use of commercial fuels are key indicators of economic growth; this can also be extended to the manufacturing sector. Output from this sector was expected to be closely associated with the level of commercial energy used in this sector.

### **1.3 Kenya's Energy Profile**

Just like most of the developing countries, Kenya has a dualistic economy comprising, the formal and informal sectors (which also include the traditional sector). This dualism is an important determinant of energy supply and demand (Nyoike and Okech, 1992). Wood fuel (firewood and charcoal) is the main energy source in the traditional sector. The formal sector, which comprises commerce, industry and the urbanized communities, largely depends on fossil fuels and electricity.

In Kenya, sources of energy comprise both commercial and non-commercial alternatives. Commercial sources of energy include petroleum products and electricity, while non-commercial ones, comprise biomass, and to a lesser extent solar energy, wind power and biogas.

Crude oil is the leading source of the world modern energy supply. In Kenya, petroleum fuel, a major source of modern energy accounts for about 20 per cent of the total primary energy consumption. Kenya does not have a domestic source of oil; hence it relies on imported petroleum for its local consumption.

Most of Kenya's crude oil and refined petroleum products imports originate from the Middle East, especially from Saudi Arabia, Iran, Kuwait and Qatar. Crude oil import is refined in the country's only refinery at Mombasa into liquid petroleum gas (LPG), regular motor gasoline, premium motor gasoline, illuminating kerosene, light diesel oil, industrial diesel oil and fuel oil.

Electric power is another important source of energy in Kenya. It contributes about 10 per cent of the total energy needs. This type of energy is derived from hydro, wind, thermal and geothermal sources. In the past, KPLC carried out distribution and sale of electricity. Reforms that were introduced in the power sub-sector between 1994 and 2000 led to the separation of power generation and marketing. KENGEN is now the major producer of electricity in Kenya. KENGEN does not satisfy the demand for electricity in Kenya and because of this, private producers have been commissioned to supplement the power generated by it especially in times of drought. These private producers are in two categories, namely, the Independent Power Producers (IPPs) and the Emergency Power Producers (EPPs). Most of the electricity in Kenya is hydro-based. The contribution of hydroelectricity to total electricity supply was 67, 42 and 44 per cent in the years 1999, 2000 and 2001 respectively (Republic of Kenya 2002a). The contributions of the IPPs for the same periods were approximately 9, 20 and 30 per cent, respectively. In addition, to the above supplies of electricity, Kenya has an agreement with the Uganda Electricity Board (UEB) to supply the country with 30 MW annually.

Although the domestic power producers, plus supply from UEB, have managed to meet the country's total electricity demand, the heavy reliance on hydropower is a problem especially during periods of drought when less electricity is produced leading to power rationing. For example in September 1999, massive power rationing was done due to acute hydro generation shortfall. Power rationing has negative effects in the productivity of most of the sectors of the economy especially the manufacturing sector and it also discourages additional investment in the economy.

Biomass is another source of energy in Kenya. Biomass resources are derived from forest formations such as closed forests, woodlands, bush lands, grasslands, farmlands, plantations and agricultural and industrial residues. These resources include wood fuels (fuel wood and charcoal) and agricultural residues. This type of energy leads in terms of total supply of energy in the country, supplying about 70 per cent of Kenya's total energy needs. About 80 per cent of the Kenyan population depends on wood fuel for domestic energy needs, providing 93 per cent and 80 per cent of the rural household and urban area energy requirements respectively (Republic of Kenya, 2000a). These forms of energy are mainly utilized in the manufacturing, commercial, transport and the residential sub-sectors.

#### **1.4 Statement of the Problem**

The manufacturing sector in Kenya is the second largest user of petroleum products and the largest user of electricity. The sector uses about 25 per cent and 41 per cent of total petroleum and electricity consumed in Kenya, respectively. Utilization of electricity in this sector has been growing over the years and is expected to continue growing indicating that the cost of energy in this sector has also been growing over time. Adjustments have been done on electricity retail prices, but their effects on utilization of the various forms of energy by the manufacturing sector

are not well known. On the other hand, use of petroleum products by this sector was erratic over the study period.

In the thirty six years spanning the period 1970 through 2005, the energy sector experienced several events including the droughts of 1980s and 1999-2001, the oil crises of 1973, and 1979, the oil glut of 1986, and the energy reforms which were gradually introduced between 1994 and 2000. At the same time, nominal value added in the manufacturing sector, increased by 719 per cent in the period 1970-2005. The cost of non- energy inputs (capital and labour) has been changing during this period (see table 1.1). The effects of these events and the changes in the costs of non-energy inputs on energy use, in a larger energy-consuming sector such as the Kenyan manufacturing, are not fully known.

Studies that have been done in Kenya (see for example; Senga *et al.*, 1980; Kimuyu 1988), have analyzed economy-wide demand for energy but none has singled out the manufacturing sector, which is a major user of commercial energy. Other studies (see for example, Gor 1994; Sasia 1987) have investigated energy demand by residential sector and energy product demand. Almost all the studies have used time series data where stationarity of the data was assumed. None investigated the time series properties of the data. Results obtained from most of these studies are therefore questionable given that proper account of time series properties of the variables used in their respective investigations was not done. In contrast to previous studies, this study incorporates increasingly popular econometric diagnostic techniques, stationary tests (Engle and Granger 1987) error correction model and co-integration. Since the economic variables used in the energy utilization model, such as output, and tariff are likely to be endogenous, estimating energy utilization by a single equation may produce simultaneous bias and hence lead to biased and inconsistent estimates (Lin, 2003). Both of these problems can be

overcome with the help of the co-integration model. Co-integration analysis identifies the long-run equilibrium relationship if it exists.

## **1.5 Research Questions**

This study addressed the following research questions:

- (i) What are the characteristics of the energy market in Kenya?
- (ii) What are the factors determining energy utilization in Kenya's manufacturing sector?
- (iii) What is the degree of substitution among energy forms and among total energy and non-energy inputs?
- (iv) What policy implications can be drawn from the study results?

## **1.6 Objectives of the Study**

The overall purpose of this study was to analyze the factors that influence energy utilization in Kenya's manufacturing sector, and to determine substitution possibilities between energy forms and among total energy and other non-energy inputs within the Kenyan manufacturing sector over the 1970-2005 period. The specific objectives of the study were to:

- (i) Describe the characteristics of the energy market and show how the market affects energy utilization.
- (ii) Identify the determinants of energy utilization in the manufacturing sector and estimate the energy demand functions.
- (iii) Estimate the degree of substitution among energy forms and among total energy and other non-energy inputs.
- (iv) Draw policy implications from the results of the study.

## 1.7 Significance of the Study

Studies on energy utilization with respect to the whole economy or to a specific sector have attracted a lot of attention as a result of the international oil crises of 1973 and 1979. Currently, this topic is still of interest due to global warming and the role played by the greenhouse gases and their link to energy consumption.

Energy consumption analysis is an important component of integrated energy planning and policy in developing countries such as Kenya. Planners and policy-makers need to have a good understanding of the factors affecting growth and pattern of energy before they can proceed to make demand projections for the future. Given the capital intensity and long gestation periods of energy investments, supply difficulties and adverse effects of energy shortages, detailed studies on the demand for energy studies need to be undertaken at the aggregate and sectoral levels. An analysis of the influence of price and non-price variables on energy consumption would also be necessary for designing policy measures that can lead to energy conservation.

Information on the degree of energy substitution is important in predicting the effects of energy shortages and it has important economic policy implications. For example, higher energy prices may induce cost minimizing firms to substitute energy for capital and labour. Also, high price elasticities of the demand for oil may induce firms to substitute towards capital-labour combination and other forms of energy. This will also affect capital and labour utilization. If energy is price-inelastic, then when price of energy increases, demand for energy goes down but by a smaller proportion than the price increase. Thus, policy-makers would have to find ways to increase local production of alternative forms of energy because energy demand would not respond much to price. Similarly, capital-energy complementarity

is not desirable because it will discourage capital formation within the sector especially when price of energy increases. These will affect the growth of the manufacturing sector that depends on capital accumulation.

The motivating factor for this study is that studies have been done focusing on total consumption of energy (see Senga *et al.*, 1980). Moreover, focus has been on energy consumption in the transport and residential sectors (see Sasia 1987; Gor 1994) with near total neglect of the manufacturing sector. So far no econometric study has been done on energy usage in Kenya's manufacturing sector focusing on causal analysis. The manufacturing sector is the major consumer of electricity and second largest consumer of petroleum products and therefore, a detailed study on utilization of energy in this sector has major policy implications. Finally, the manufacturing sector, which is the source of modernization in any country, as it continues to develop, is accompanied by increased consumption of modern forms of energy. Given that Kenya imports all its petroleum products, the manufacturing sector, being the second largest consumer of this form of energy, will continue to contribute more to overall balance of payments position in the country. It was, therefore, necessary for this study to focus on the manufacturing sector.

## **1.8 Scope of the Study and Organization of the Thesis**

This study covered energy consumption by the Kenyan manufacturing sector over the period 1970-2005. The choice of this period was governed by the availability of statistics which are important in estimating energy consumption. The thesis is organized into five chapters. The preceding chapter introduced the problem that was investigated by this study. In chapter two, the relevant literature is reviewed and the theoretical model is developed. Chapter three

presents the methodology of the study and the empirical model used in this study. In chapter four, the empirical findings are presented and discussed. Chapter five contains the summary, conclusions and recommendations of the study. Bibliography and the appendices are provided at the end.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Introduction

This chapter reviews the empirical studies that have been done on the determinants of energy use, the degree of substitution among energy forms and among energy and other non-energy inputs. The chapter reviews studies done outside and within Kenya. The theoretical framework is also presented in this chapter.

#### 2.2 Energy Demand Studies in Other Countries

Hu (2004), studied energy consumption in China by use of the input-output model of the form:

$$Q^E = B * F * I \quad 2.1$$

Where,  $Q^E$  is total energy consumption (energy output of the energy sector),  $B$  is the Leontief inverse matrix,  $F$  represents final demand for the output of  $i$ th industry, while  $i$  is the unit vector.

Using China's input/output tables of 1987 and 1997, Hu hypothesized that technical changes and structural changes influence energy consumption. The results of the study suggested that changes in direct energy input requirements in various industries were the dominant force behind the falling energy intensities. Structural changes were found to be non-significant in affecting energy intensity.

The input-output model has several limitations (Kimuyu , 1988). The main one is that it is based on restrictive assumptions such as, fixed input to output ratio in production process, constant utilization shares and zero own and cross price elasticities of demand. It does not take

into account substitution possibilities in either production or consumption and its application is only limited to the short term.

Researchers have argued that in developing countries where official time series data are either unavailable or unreliable, Input-Output tables are very helpful (Kimuyu, 1988). But this requires that the Input-Output tables are available or easy to generate, which in most of the developing countries is hard to do. Because of this, the Input-Output model was inappropriate for this study.

Most of the analysts who have used these kinds of models, introduce dynamism to static models by either allowing the energy using equipment to change or by including consumer expectations. Given that expectations are hard to estimate directly, they are commonly indirectly estimated using the reduced forms models. The commonly used adjustment model takes the following form:

$$E_t - E_{t-1} = \sigma(E_t^* - E_{t-1})$$

2.2

Where,  $0 < \sigma < 1$

The variables  $E_t$ ,  $E_{t-1}$  represent actual demand for energy and lagged energy demand, respectively and  $E_t^*$  is desired demand for energy.  $\sigma$  is the coefficient of adjustment. This model leads to energy demand specification with lagged dependent variable as one of the explanatory variables, making it autoregressive. Most of the analysts express the energy demand or consumption function in log-linear form and use ordinary least squares method of estimation. The studies mainly differ in terms of the variables used in each function. Several studies have used this model, including Dayo and Adegbulugbe (1987); Kimuyu (1988); Manzoor (2002); Gor (1994); and Sasia (1987).

Dayo and Adegbulugbe (1987), investigated oil demand function for Nigeria by use of the following function:

$$Q_t = A(P_t^\beta I_t^\alpha)^{1-\lambda} Q_{t-1}^\lambda \quad 2.3$$

Where,  $1 \geq \lambda \geq 0$

The parameters  $\beta$ , and  $\alpha$ , measured price and income elasticities, while  $\lambda$  measured the geometric adjustment lag. The variable,  $Q_t$ , represents current year petroleum product consumption per capita, which the function specified to be influenced by the composite price of petroleum products ( $P_t$ ), Gross Domestic Product per capita ( $I_t$ ), and lagged petroleum product consumption per capita ( $Q_{t-1}$ ). The Ordinary Least Squares (OLS) method was used to estimate the model using time series data for the period 1965-1983. The study found that all the hypothesized independent variables were significant in influencing Nigeria's petroleum consumption. Demand was found to be price elastic (-1.117), when price was expressed in real terms, and price inelastic (-0.8) when price was expressed in nominal terms. This inconsistency was attributed to the use of Consumer Price Index (CPI) to deflate data, which were considered to be unreliable. Demand was found to be income inelastic (0.368) when income was expressed in real terms and elastic (1.033) with nominal income. The study preferred the model expressed in nominal terms since it gave results that both agreed with Nigeria's experience and consistent with other studies.

Manzoor (2004) estimated residential energy demand for Iran using annual data over the period 1971-2002. The study used a two-level model of energy demand as follows:

$$S_{it} = f(S_{i,t-1}, PEL_t, PNG_t, PO_t) \quad 2.4$$

$$PE_t = \sum_i S_{i,t} * P_{i,t} \quad 2.5$$

$$E_t = h(E_{t-1}, PE_t / CPI_t, Y) \quad 2.6$$

$$Q_{i,t} = S_{i,t} * E_t \quad 2.7$$

Where  $i$  = Electricity (EL), natural Gas (NG), and Oil (O);  $S_{i,t}$  = market share of energy source  $i$  in total residential energy demand in year  $t$ ;  $PE_t$  = price of total energy in year  $t$ ,  $P_{i,t}$  = Price of energy source  $i$  in year  $t$ ,  $E_t$  = total energy consumption in year  $t$ ;  $CPI_t$  = consumer price index in year  $t$ ;  $Y_t$  = real total consumer expenditure in year  $t$ ;  $Q_{i,t}$  = consumption of energy source  $i$  in year  $t$ . Variables in equations (2.5) and (2.7) were expressed in log form and the models were estimated by use of OLS. The study found real price of energy and household expenditure to be significant determinants of total energy consumption by the household sector. The price and income elasticities (-0.148 and 0.623 respectively) suggested that total residential energy demand was both price and income inelastic. The study used only two explanatory variables, income and price of energy leaving out other independent variables such as population and energy efficiency.

Lin (2003) specified energy total electricity demand in China as:

$$\ln Q = a + b \ln GDP + c \ln P + d \ln POP - e \ln M2 - f \ln EF + e \quad 2.9$$

Where  $Q$  is electricity demand,  $GDP$  was Gross Domestic Product,  $P$  is price of electricity,  $POP$  was population  $M2$ , was structural changes, and  $EF$  is efficiency. The coefficients  $b$ ,  $c$ ,  $d$ ,  $e$ , and  $f$  were electricity demand elasticities. All explanatory variables were found to be statistically significant in determining electricity demand in China. Electricity demand was found to be price inelastic (- 0.032) and almost income elastic (0.940).

Filippini and Pachauri (2002) argued that in the short-run when energy prices increase, there were two types of energy consumer responses: in the short-run, the consumer would lower the

rate at which the current stock of appliances is utilized such as by adjusting the temperatures of thermostats and water heaters. In the long run, since changes in energy price might result in changes in relative prices of inputs, the consumer would alter the mix of inputs. This would lead to an adjustment of the consumer's energy using equipment. Thus more efficient appliances would substitute less efficient energy appliances. Static models have been widely applied in energy demand studies of this type including Bjorner and and Jensen (2000).

Jean (2000), using annual data of the period 1970-1997, carried out a study on total energy demand for the Province of Quebec, Canada. The study modelled energy demand using two integrated levels. At first level total energy demand was made a function of lagged value, aggregate real energy price, real income and heating degree-days. At the second level, (disaggregated) market share (of coal, electricity, natural gas and oil) was made a function of the corresponding lagged share and relative prices of energy sources. Using OLS method of estimation, the study found that for the total demand for energy, lagged dependent variable, real price of energy and heating degree-days were statistically significant and had the expected right signs in all the sectors. In the industrial sector, real price was found to be statistically insignificant. In the market share equations, the price variable had the expected negative sign and was statistically significant except in the industrial sector where it was found to be insignificant. Substitution possibilities were also observed between oil and electricity in all the sectors. Lagged energy levels were also significant in all the sectors. Jean's results conform to theory but these results are questionable given that the study used time series data, which were assumed to be stationary.

Mahmud (2000) studied the role of energy in the manufacturing sector of Pakistan using time series data of 1972-1993. The study found that high-energy prices do not adversely affect investment in capital. Substitution possibilities between energy and non-energy were found to be limited. The cross price elasticities indicated that there were substitution possibilities between gas and electricity.

Christopoulos (2000) examined substitution between energy and capital and labour in the manufacturing sector of the Greek industry between 1970 and 1990. The study used the dynamic total cost translog function to represent the production technology. The study found no evidence of inter-fuel substitution except for diesel and electricity. Results of the total cost function suggested that all the inputs were substitutes but with limited substitution possibilities. For example, the cross price elasticity between energy and capital was found to be 0.03 while that one between labour and energy was 0.02.

Bjorner and Jensen (2000), using micro panel data for the years 1983, 1985, 1988, 1990, 1993, 1995, and 1996, analyzed the effects of energy tax, subsidies and energy agreements on energy demand by industries in Denmark. This study used a log-linear model with energy as the dependent variable and value added, relative energy prices, price of energy, energy agreements and energy subsidies as the independent variables. All variables were measured in logarithms.

The study found that energy price had a negative (-0.44) effect on quantity of energy demanded. Energy audit, which was one of the agreements the companies signed, had a significant effect suggesting that these audits reduced electricity consumption by about 7 per cent (significant at 10 percent) and total energy consumption by about 13 per cent (significant

at 5 percent). The energy agreement should be interpreted with care given that their significance was low. With respect to value added, electricity price and energy prices had the expected signs and were statistically significant.

Hodge (1999), using a double log model estimated United States energy demand elasticities. The study modelled total energy as a function of consumer price energy index, income and efficiency. The study found that energy demand was statistically price inelastic and quite responsive to income changes both in the short- and long-run. A one-percentage increase in per capita income resulted in almost equal percentage increase in energy consumption. On the other hand, the study found that if the level of technology as measured by miles per gallon went up by one per cent, energy consumption fell by a little less than 0.5 per cent.

Al-Azzam and Hawdoun (1997) estimated demand for energy in Jordan using the following model:

$$\log Q_t = a + b_1 \log P_t + b_2 \log Y_t + b_3 \log A_t + b_4 D_t + e \quad 2.8$$

Where,  $Q_t$  is long-run aggregate energy consumption, which the study hypothesized as being influenced by real price of energy ( $P_t$ ), real income ( $Y_t$ ), total area constructed in square meters ( $A_t$ ), and a dummy variable for conflict and political instability  $D$ . The parameters  $b_i$  are energy demand elasticities. The study took the view that construction activity was a good proxy for development, involving resettlement and urbanization and has great impact in other economic activities that are themselves users of energy. The Al-Azzam and Hawdoun (1997) 's study is an improvement to most of the earlier studies given that it employed recent techniques of co-integration and error correction modeling and the application of the dynamic OLS method developed by Stock and Watson (1993). Income, construction activity and political instability emerged to be significant in influencing long run aggregate energy demand

in Jordan during the sample period under study. Energy was found to be price inelastic (-0.347). This variable was, however, found to be insignificant in determining energy use. This suggested that taxes alone were unlikely to be effective as government tools for energy conservation or environmental improvement. The study found income elasticity for the total energy demand to be close to unity (0.98) implying that economic growth was likely to be accompanied by proportional increases in energy demand and hence environmental degradation.

Chishti and Mahmud (1990) using time series data for the period 1960-1980 estimated the substitution possibilities between energy and non-energy inputs in the large-scale manufacturing sector of Pakistan. The study used the translog cost function to come up with the coefficient estimates. The study found little inter-fuel substitution relationships. Energy and labour were found to be substitutes while energy and capital were found to be complements.

Saicheua (1987) estimated the input demand functions of capital, energy and labour using the translog model for Thailand's manufacturing sector. The study covered the period of the first oil shock, 1974-1977. The study found energy to be price elastic, while price elasticity of demand for labour was close to unity and that for capital was inelastic. The energy elasticity was very high ranging between -2.60 and -1.50. Although with the right sign, this finding was rare which was attributed to the study period 1974-1977, the period of oil price shock, and energy conservation measures taken by Thailand, such as better maintenance of machines and investment in waste control. The manufacturing sector as a whole was able to reduce energy use effectively in response to rising energy prices between 1974 and 1977.

### **2.3 Studies on Energy in Kenya**

Republic of Kenya (2001a) carried out a detailed survey on Kenya's energy demand, supply and policy strategy for households, small-scale industries and service establishments. The study found that rural and urban households often consume a mix of both traditional and conventional energy types depending on households' income. Poor households tended to use more of traditional energy resources while the high-income families were found to use more of the modern energy resources. On average, 96 per cent of the surveyed households (urban and rural) use firewood, 82 per cent used charcoal, 62 per cent used wood waste, 100 percent used farm residue, 29 per cent used electricity and 12 per cent used petroleum products. For the cottage and other industries surveyed, 4 per cent used firewood, 18 per cent used charcoal, 38 per cent used wood waste, none used farm residue, 70 per cent used electricity and 55per cent used petroleum products.

Gor (1994), using a log-linear model carried out a study on consumption of commercial energy in the residential sector of Kenya over 1970-1990 periods. The types of energy investigated in this study were: Illuminating kerosene, LPG, and electricity. Each type of energy was expressed as a function of own price, cross prices, GDP, employment, population, past fuel consumption levels, and oil crises. By use of the OLS method of estimation, the study findings revealed that nominal data gave better results than real data. The study found that for all commercial types of energy studied (kerosene, LPG, and electricity) own prices were statistically insignificant. Wage employment, population and price of LPG were significant in explaining changes in kerosene consumption, while income, population and past levels of consumption were significant in explaining the changes in consumption levels of LPG. Wage

employment and past levels of electricity consumption were the only significant variables for the electricity demand. Gor's (1994) findings are suspect given that the study used time series data which was assumed to be stationary. Also, wage employment and populations were highly correlated and this put the findings of the study in doubt. The study seems to have done no diagnostic tests of various econometric problems such as autocorrelation, multicollinearity and model specification errors.

Kimuyu (1988), using a dynamic log-linear model, investigated Kenya's demand for energy over the 1963-1985 period. The study found that demand for energy in Kenya was quite price inelastic and responded more readily to income changes than to price changes in both the short and long runs. The estimated short-run price elasticities of demand for fuels ranged from 0.161 for domestic electricity to 1.05 for coal, with an unweighted average of .330. The long-run price elasticities ranged from 0.527 for LPG to 3.00 for off-peak electricity, with an unweighted average of 1.357. 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 was found to be 0.211 and 1.03, respectively. The findings of the study suggested that income affects energy demand. The short-run income elasticities ranged from .259 for motor spirit to 0.863 for oil, with an unweighted average of about .506. On the other hand, long-run income elasticities ranged from 0.899 for fuel oil to 5.83 for gas oil with an unweighted average of about 2.275.

Sasia (1987), using annual data over the period 1964-1985, did a study on demand for gasoline and light diesel in Kenya's transport sector. The study used Ordinary Least Squares regression method to estimate each type of the fuel demand functions. The study expressed each type of

energy demand as a function of oil crisis, respective energy price, income, relative energy price and lagged energy value. The results showed that the price of gasoline was an insignificant explanatory variable on demand for gasoline and that gasoline demand responds more significantly to income. Previous gasoline consumption levels had a significant effect on gasoline demand. With light diesel, apart from own price, all the variables had the expected signs, and were significantly different from zero. Own price was found to be insignificant but with the negative effect on demand for light diesel as expected. The coefficient of relative price (0.27) suggested substitution possibilities between light diesel and gasoline.

The Kenya Central Bureau of Statistics (CBS) did a study on energy sector using descriptive statistics to summarize energy situation in Kenya over the 1969-1977 period (Republic of Kenya, 1978). The study identified oil as the major commercial source of energy in Kenya and yet it was wholly imported. The study suggested that the major factors explaining the economy's problems by that time were the oil import bill and the high oil prices.

Beijer Institute (1984) carried out a detailed study in Kenya on energy and development, constraints and opportunities. They found that own price, household size and income, explained significantly the changes in consumption of kerosene. Since 1980, there have been several changes that have taken place in Kenya, which include population growth, increased urbanization, technological developments in the energy sector, and more people being employed. This generally shows that the country might have gone to a higher development level, hence the need for another study.

Jones (1983) carried out a study on energy use by the major Kenyan industries. The study used firm level data from 160 firms collected in the year 1981. The study found that pulp and paper, glass, rubber products, metal and cement industries were the most energy -intensive industries. Out of the surveyed firms, 46 per cent had taken energy saving measures such as recovery of waste heat, improvement in electrical efficiency and process changes. The study reported that some firms had substituted imported petroleum for less costly or domestic fuels. There was evidence of increased utilization of coffee husks, tyre scrapping and wood waste as energy sources. There have been several changes in the energy sector since 1981, such as reforms in the energy sector, structural changes in the economy, and droughts leading to rationing of electricity. With these changes, undertaking another study with recent data set is worthwhile.

Mureithi, Kimuyu and Ikiara (1982), using a translog model, studied the impact of increased energy costs on balance of payments, choice of production technology and real income in Kenya. The study also analyzed substitution possibilities between different types of energy and between energy and non-energy factors of production. Results of the study suggested that labour and energy were complementary in production, while energy and capital were substitutes. The results of the study also revealed substitution possibilities across different fuels. The study showed that it was the direct costs of raw materials rather than that of energy that increased most rapidly over 1964-1976 period, suggesting that energy costs were not responsible for the economic problems the country was facing.

The World Bank (1982) assessed issues and options in the Kenyan energy sector. The mission found deforestation and burden on the balance of payments imposed by oil import bill to be the major problems in the energy sector. The mission recommended the stepping up of oil

exploration, increased utilization of coal, replacement of thermal power generation by geothermal and hydroelectricity generation, better mix between imported petroleum products and exports, improvement of afforestation programmes and efficiencies of charcoal conversion technologies, wood and charcoal appliances. The study, however, did not carry out any econometric energy demand analysis to establish the factors influencing energy use in Kenya.

Senga, House, and Manundu (1980) assessed supply and demand for commercial energy in Kenya using annual data of 1950-1977. They used the following model:

$$D_t = A Y_t^a P_t^b e_t \quad 2.10$$

Where  $D_t$  = consumption of energy in year  $t$ ,  $Y_t$  = GDP in year  $t$  measured in base year prices,  $P_t$  = price of energy product under consideration in year  $t$ ,  $e_t$  is the error term, while “ $a$ ”, and “ $b$ ” are short-run income and price elasticities of demand.

The study found that total energy consumption responds highly and significantly to GDP growth. With a one per cent increase in GDP, energy consumption increased by the same margin. The price variable was found to be statistically insignificant in the total energy function although with the expected negative sign. For the majority of the energy types, price was found to be a significant determinant of energy demand.

The empirical model seemed to be mis-specified by considering only two independent variables, income and price of energy. The study used time series data where stationarity was assumed as the study used OLS method of estimation without testing for existence of unit roots. This suggested that the results were unreliable or questionable. The study also used

static model where the authors concentrated on stock utilization and ignored possibilities of stock adjustment given that their study covered a long period. The elasticities obtained by the study were short-term and could not be applicable for long-run forecasting.

In a study of energy demand and conservation in Kenya, Schipper (1980) disaggregated important energy uses into physical and economic activity levels as well as energy intensities. The study pointed out that low incomes made it difficult for the average Kenyan to purchase the equipment needed to make use of electricity at the household level. The study concluded that there was evidence of attempts to conserve energy but many opportunities remained unexploited.

## **2.4. Overview of Literature**

The literature reviewed above indicates that several studies have been done all over the world on energy demand. Several models have been used to estimate energy demand including static, input-output, translog, and dynamic models. Several variables which affect energy demand, have been identified and they include: own price, cross price, income, heating degree days, structural changes in the economy, lagged energy demand, energy efficiency, total area constructed, technology, economic stability, taxes, subsidies, energy agreements, employment, population, prices of labour and capital, and oil crisis.

In Kenya, most of the studies on energy have used time series data. One doubts the results obtained from these studies given that the data were assumed to be stationary and that not all determinants of energy use were taken into account. This study bridges this gap by taking into

account the time series properties of the data, by using current data, and by incorporating the prices of non-energy inputs, technology, and by controlling for unusual events in energy consumption such as droughts. In contrast to previous Kenyan studies, this study used the translog model to estimate the parameters of energy and non-energy demand functions fully taking into account the time series properties of the data.

## **2.5 Theoretical Framework**

### **2.5.1 Introduction**

This section presents the energy utilization model derived from economic theory. The input demand function developed is founded on the cost minimization theory of the firm (Henderson and Quandt 1980; Silberberg .1990).

### **2.5.2 Cost Minimizing Behaviour of Firms**

The literature on production, costs, and input demand has evolved in several directions. In the area of models of production, the classic paper by Arrow *et al.*, (1963) questioned the inherent restriction of Cobb- Douglas model that all elasticities of factor substitution were equal to one. Researchers have since developed numerous flexible functions that allow substitution to be unrestricted (see for example, Berndt and Christensen, 1973). Similar developments have taken place in studies dealing with commodity demand analysis (see Christensen, 1975). In this section, the total cost function and the input demand models are developed from the general production function following the work of Saicheua (1987).

Energy (E) can be regarded as an input in production in the same way as other inputs such as capital (K) and labour (L). The production function facing the firm is assumed to take the following general form:

$$Y=f(E,K,L,T)$$

2.11

Where, Y is the target output, E is energy, K represents capital, L represents labour, while T represents the state of technology and other exogenous changes. Here, it is assumed that the only factors of production are capital, energy and labour. It is assumed that  $f(E,K,L,T)$  is finite for every E,K,L and T, continuous for all non- negative Y output and inputs and monotonicity is valid for  $f(E,K,L,T)$ . It is also assumed that the production function is strictly concave and is weakly separable in the factors of production.

Given the production function (2.11) and the associated assumptions, the cost function can be derived. According to duality principles, Samuelson (1947), Uzawa (1964) and Shephard (1970), there is a cost function equivalent to the production function that can represent the technology of production and vice versa. It is assumed that the cost function corresponding to the production function can be represented by:

$$C= C(P_i, Y, T)$$

2.12

Where,  $P_i$  input prices (  $i=1,2,3$ ). The cost function (2.12) is considered, similarly to production function (2.1) to be twice differentiable in  $P_i$  and T, finite for every  $P_i, Y \geq 0$  and T, continuous in Y and  $P_i$ , linearly homogeneous in  $P_i$  and  $Y \geq 0$ , non- decreasing in Y and  $P_i$  and concave in  $P_i$ , and is weakly separable. It is also assumed that the factors of production are capital (K), labour (L), and energy (E). Where energy includes electricity (Ele), and oil (O), the variable technology (T) is also assumed to affect cost of production. The state of technology holding other factors constant can increase or decrease the cost of production.

The cost function can be written as:

$$C= g(P_E(P_O, P_{EL}), P_K, P_L, Y, T)$$

2.13

Where  $P_K$  represents price of capital,  $P_L$  the price of labour,  $P_E$  is the aggregate price of energy, that is the function that aggregates the energy prices of two components of energy,  $P_O$  price of oil, and  $P_{El}$  price of electricity.

According to the theory of production, a firm purchases energy from the market to serve as an input that is used in the production process for goods and services. Demand for energy is therefore, a derived demand. Assuming that firm  $j$  is a profit maximizer, such a firm should produce at the minimum possible cost. It is, therefore, assumed that this firm aims at minimizing total cost (C) subject to the technological constraints.

$$\text{Min} \sum (P_i X_i) = \text{TC} \quad 2.14$$

$i$  =energy, capital and labour, and TC represents total cost.

Under the hypothesis of total cost minimization, the cost function may take various forms. The translog form is one which was preferred in this study because it is flexible, it does not hold the inputs at a fixed proportions at different output levels, it does not restrict the substitution possibilities between inputs, it allows for interactive effects of the independent variables and is therefore, more realistic.

The cost function (C) was approximated by a translog second-order approximation (Christopoulos, 2000, Greene, 1990, Christensen *et al*, 1973).

$$\begin{aligned} \ln TC = & \beta_0 + \sum_i \beta_i \ln P_i + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \frac{1}{2} (\theta_1 (\ln Y)^2 + \theta_2 T^2) \\ & + \delta_1 \ln Y + \delta_2 T + \sum_i \alpha_i \ln Y \ln P_i + \sum_i \alpha_i \ln P_i T + \theta \ln Y T \end{aligned} \quad 2.15$$

$i, j$  = E(energy), L(labour), K(capital), TC = total cost

Under the conditions of perfect competition, partially differentiating equation (2.15) and using Shephards Lemma (1970), yields the input demand functions in terms of cost shares (Greene, 1990):

$$S_i = \frac{\partial \ln TC}{\partial \ln P_i} = \frac{P_i X_i}{TC} = \beta_i + \sum_j \gamma_{ij} \ln P_j + \sum_i a_i \ln Y + \alpha_i T. \quad 2.16$$

Where  $S_i$  is the cost share of the input  $i$  demanded and  $\sum_i S_i = 1, i = K, L, E$ .

Homogeneity, additivity and symmetry conditions for prices are necessary properties of a well-behaved cost function and were imposed on the model through the following parameter restrictions:

Additivity condition expressed as:  $\sum_i \beta_i = 1$ ,

Symmetry condition expressed as:  $\gamma_{ij} = \gamma_{ji}$ ,

Homogeneity condition expressed as:  $\sum \gamma_{ij} = \sum a_i = \sum \alpha_i = 0$ ,

Where,  $i=K,L,E$  2.17

The restrictions (2.17) are necessary and sufficient conditions ensuring TC is linearly homogeneous in input prices. However, the price of energy (PE) is considered also to be an aggregate function. This aggregate function can be represented by a homothetic translog cost function with constant returns to scale. The translog cost function corresponding only to various energy components may be expressed as:

$$\ln P_E = \beta_0 + \sum_i \beta_i \ln P_{Ei} + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln P_{Ei} \ln P_{Ej} \quad 2.18$$

The following energy cost share equations are implied by Shephards Lemma:

$$S_i^E = \beta_i + \sum_j \gamma_{ij} \ln P_j \quad 2.19$$

where  $i,j=Ele, O$

Where  $S_i^E$  is the cost share of energy form  $i$  in the total energy cost of the manufacturing sector. Again, the adding up criterion  $\sum_i S_i^E = 1, i = Ele, O$  should be satisfied and the properties of neo-classical production theory require the following parameter restrictions to be satisfied:

$$\sum_i \beta_i = 1, \quad \gamma_{ij} = \gamma_{ji}, \quad \sum_j \gamma_{ij} = 0, i = Ele, O \quad 2.20$$

By definition, the cost shares of the various types of energy utilized should add up to unity, so one equation was dropped (the oil) during estimation to avoid a singular matrix, i.e oil is the reference energy input.

The model shows that the variables that influence use of energy are: own price, cross price, technology, output and prices of other non-energy inputs. Other factors including energy efficiency, the cost of energy appliances, and the level of employment influence the level of energy utilization by the firm.

## CHAPTER THREE

### METHODOLOGY

#### 3.1 Introduction

In this chapter, the empirical model is presented. Definitions of the variables and the techniques used to investigate time series properties of the data are presented as well. The techniques used to test for correlation and multicollinearity among variables are also presented. To achieve the objectives of this study, quantitative data were collected and analyzed. Data and the sources are explained and then followed by the method of data analysis.

#### 3.2 Empirical Model

The empirical model based on equation 2.16 was represented by the following input utilization function (X):

$$X_{it} = f(P_{it}, Y_t, T, F_t) \quad 3.1$$

$X_i$ = input i, i= energy, capital and labour, P= price of input i, Y= output, T= technology, F= energy efficiency, t= time (t=1, 2, ..., 36)

The following input share equations were estimated:

$$\begin{aligned} S_E &= \beta_E + \beta_{EK} P_K + \beta_{EL} \ln P_L + \beta_{EE} \ln P_E + \beta_{EY} \ln Y + \beta_{ET} T + \beta_{EF} \ln F + \beta_{ED} D + U_E \\ S_L &= \beta_L + \beta_{LK} P_K + \beta_{LL} \ln P_L + \beta_{LE} \ln P_E + \beta_{LY} \ln Y + \beta_{LT} T + \beta_{LF} \ln F + \beta_{LD} D + U_L \\ S_K &= \beta_K + \beta_{KK} P_K + \beta_{KL} \ln P_L + \beta_{KE} \ln P_E + \beta_{KY} \ln Y + \beta_{KT} T + \beta_{KF} \ln F + \beta_{KD} D + U_K \end{aligned} \quad 3.2$$

Where,

$i, j$ = energy (E), capital (K) and labour(L),  $\beta_i, \beta_{ij}$  are parameters that were estimated.

$D$  = Dummy that represented the unusual events such as political elections in the country,  $P_i$  = price of input  $i$  (E, K,L),  $U_i$  = the error term

$S_i$  = Cost share of input  $i$  in the total cost of the manufacturing firms

The following parameter restrictions were imposed:

$$\sum \beta_i = 1, \sum_i \beta_{ij} = \sum_j \beta_{ji} = 0, \beta_{ij} = \beta_{ji}, \sum \beta_{iY} = 0, \sum \beta_{iT} = 0, \sum \beta_{iF} = 0 \quad 3.3$$

After obtaining the estimates of the parameters  $\beta_i$ ,  $\beta_{ij}$ , the Allen-Uzawa elasticities of substitution ( $A_{ij}$ ), the cross price elasticities ( $E_{ij}$ ) and own price elasticities ( $E_{ii}$ ) were calculated by use of the following formulae: (Greene, 1990, pp 528)

$$E_{ii} = A_{ii} \cdot S_i \quad 3.4$$

Where

$$A_{ii} = (\beta_{ii} + S_i^2 - S_i) / S_i^2$$

$$A_{ij} = (\beta_{ij} + S_i S_j) / S_i S_j \quad 3.5$$

$$E_{ij} = A_{ij} S_j \quad 3.6$$

If, however, the full system is estimated, the problem of singularity is noted since the cost shares add up to one. The study, therefore, dropped the capital share equation and identified its parameters using the restrictions above. The Maximum Likelihood Method was used to estimate the parameters, since it ensures that the results are invariant to the choice of the equation dropped (Barten, 1969, Berndt and Savin, 1975).

Since the translog cost function is a local approximation to the value of any function, it required that regularity conditions be met by the data used by this study. Linear homogeneity and symmetry of the cross terms were imposed on the function. Sufficient conditions for monotonicity and concavity require the fitted cost shares to be strictly positive and the Hessian

matrix formed by the elasticity coefficients to be negative semi- definite. These requirements were met for all observations.

Before estimating model 3.2, a similar translog sub-model in energy components was estimated. The translog cost function corresponding only to the two energy components included in this study was presented as:

$$\ln P_E = \beta_0 + \sum_i \beta_i \ln P_{Ei} + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln P_{Ei} \ln P_{Ej} \quad 3.7$$

Where  $P_E$  is the aggregate price index of energy that was also taken to be the cost per unit of energy to the optimizing firm. Using Shephard's Lemma, the following energy cost shares were obtained and estimated using the Maximum Likelihood Method:

$$S_i^E = \beta_i + \sum_j \beta_{ij} \ln P_j + D_i + U_i \quad 3.8$$

$i, j =$  Electricity (EL) , Oil (O),  $S_i^E =$  The share of energy type  $i$  in total energy cost. Given that in the past studies, output, technology and energy efficiency have been found to influence energy use, they were added in the set of explanatory variables. The model that was estimated for the demand for the energy forms was, therefore, expressed as:

$$S_i^E = \beta_i + \sum_j \beta_{ij} \ln P_j + \beta_{iY} \ln Y + \beta_{iT} T + \beta_{iF} \ln F + D_i \quad 3.9$$

Again, adding up criteria and the properties of neo-classical production theory require the following parameter restrictions to be satisfied for a valid aggregate function:

$$\sum_i \beta_i = 1, \quad \beta_{ij} = \beta_{ji}, \quad \sum_i \beta_{ij} = 0 \quad 3.10$$

Two steps were followed in the estimation of the empirical equations. First, the sub-energy model (3.9) was estimated subject to the restrictions (3.10). The estimated parameters in (3.9)

were substituted into (3.7) to obtain an aggregate price index for energy. Second, the factor share equations (3.2) were estimated subject to the restrictions (3.3) using the estimated energy price index as an instrumental variable.

### **3.3 Definition of Variables**

**Total energy ( $E$ ):** This is annual total energy that was consumed by the Kenyan manufacturing sector in the period 1970 to 2005. This was generated by converting each form of energy into tonnes of oil equivalent (TOE) using international conversion factors presented in appendix IV followed by aggregating the two types of energy, electricity and oil. Because of lack of data, only two forms of energy (electricity and oil) were analyzed in this study. Oil was measured in tonnes while electricity was measured in KWh.

**Price of energy ( $P_E, P_{EL}, P_O$ ):** The price of total energy  $P_E$  measured in Kenya shillings per TOE. Values for this variable were generated by equation (3.7). The price of electricity refers to the annual average amount of money paid per kilowatt consumed by the manufacturing firms in the period 1970-2005. The price of oil was defined as the annual average wholesale price of oil as reported at Mombasa port. Electricity price was measured in Kenya shillings per KWh, while oil price was measured in Kenya shillings per tonne.

**Price of labour ( $P_L$ ):** This is the annual average real wage earnings per employee expressed in Kenya shillings of the manufacturing sector in the period 1970-2005.

**Price of capital ( $P_K$ ):** This is the cost of capital. The commercial bank real interest rate of obtaining loans was used as the proxy variable for the cost of capital. Real interest rate

was obtained by getting the difference between the nominal rates and inflation rates for each year. This cost was expressed in percentage.

**Output (Y):** This is the annual value added of the manufacturing sector in the sample period 1970-2005, expressed in Kenya shillings.

**Technology (T):** Because of lack of data, technology was represented by the trend variable. This variable was included to capture the effect of technical progress and other exogenous variables that are not directly measurable.

**Dummy (D):** Variables that were qualitative in nature that were thought to have an influence on demand for energy. Such variables that were taken to be unexpected events such as droughts, elections, and oil price shocks, may affect energy utilization. Dummy variables were taken as proxies for these variables because they could not be quantified. Two artificial values were assumed;  $D = 1$ , if the unexpected event was present,  $= 0$ , otherwise. These were detected by use of various diagnostic tests ( Johnston and Dinardo 1997). Dummies were included in the model only if they increased the predictive power of the model by improving adjusted R-squared, Durbin-Watson (DW) statistic and reduced the standard error of the regression. Therefore, models 3.2 and 3.8 were modified to incorporate the impact of these unusual events.

**Cost shares ( $S_i, S_i^E$ ):** These are cost shares computed by getting the ratio of the cost for each factor (cost of each form of energy) to total cost of production (to total energy cost),  $(P_i X_i)/TC$  or  $(P_i E_i)/EP_E$  of the whole manufacturing sector in the sample period 1970-2005.

## 3.4 Properties of time series data

### 3.4.1 Introduction

In regressing a time series variable on another time series variable, often a high R-squared is obtained although there may be no meaningful relationship between the two. This problem arises due to the presence of strong trends between variables. The high R-squared obtained is as a result of the presence of the trend but not necessarily due to a true relationship between the two time series variables. It is, therefore, important to find out whether the relationship between economic variables is true or spurious. The standard method for testing for stationarity is the unit root test, explained in the next section.

### 3.4.2 Stationarity of Data

A time series data can be thought of as being generated by a stochastic process and any data set is regarded as a realization of the underlying stochastic process. A stochastic process is said to be stationary if its mean and variance are constant over time and the value of covariance between two time periods depends only on the distance or lag between the two time periods and not on the actual time at which the covariance is computed (Gujarati, 1995). Most of the time series are random walks. In estimating such non-stationary series, one is likely to get spurious results. This problem arises because if both the time series involved exhibit strong trends, the high R squared obtained is due to the presence of the trend, but not to a true relationship between any two-time series variables. For this reason, the study carried out tests on stationarity of the variables. This study used unit root test to test for stationarity of the data. To illustrate this idea, consider the following auto-regressive model of order one AR (1):

$$Y_t = \rho Y_{t-1} + U_t \quad 3.11$$

Where  $Y$  is a vector of all variables such as quantity of energy utilized, price of energy, income, price of capital and labour, and technology in the share equations.  $U_t$  is the error term with zero mean, constant variance and is non-auto-correlated.

If in equation 3.11,  $Y_t$  is regressed on  $Y_{t-1}$  and  $\rho$  is found to be statistically equal to unity, then  $Y_t$  is said to be a random walk (a non-stationary series because it meanders in a random fashion). Alternatively equation 3.11 can be expressed as:

$$\begin{aligned}\Delta Y_t &= (\rho - 1)Y_{t-1} + U_t \\ &= \delta Y_{t-1} + U_t\end{aligned}\tag{3.12}$$

To test for stationarity in equation 3.12 the study tested the null hypothesis  $H_0: \delta = 0$ . That is, the series is non-stationary, against the alternative hypothesis  $H_1: \delta < 0$  that the series is stationary. Failing to reject the null hypothesis implies that the  $Y_t$  is non-stationary, while rejecting it implies that  $Y_t$  is a stationary time series. The Augmented Dickey-Fuller (ADF) was applied by use of the following model:

$$\Delta Y_t = a_0 + a_2 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^p \Delta Y_{t-i} + U_t\tag{3.13}$$

The idea of using many lagged difference terms is to minimize the autocorrelation in the error term. In each case, the null hypothesis was  $H_0: \delta = 0$  (there is a unit root). The test statistic on the parameter  $\delta$  was thus computed and compared to the critical values of  $\tau$  in Dickey and Fuller (1981). Failing to reject the null hypothesis implies that the series contain unit root hence is non-stationary at levels.

### 3.5. Co-integration Analysis

Most of the economic time series are non-stationary (Pindyck and Rubinfeld, 1991). This is one of the reasons why the study conducted tests on stationarity of the variables. When variables are non-stationary, to stationarise them, one takes the differences of the data. When differencing, the long-term relationship between variables, which is given at levels, is lost. This is because economic theory gives equilibrium values in levels not in the form of differences. Further, even if variables were non-stationary individually, they would be stationary if co-integrated, thus if there is some mechanism that links the variables together. Co-integration analysis was done to investigate long- run relationship among variables.

Testing for co-integration was done using the Engle- Granger two-step procedure (Granger 1986; and Engle and Granger 1987). The procedure involved testing whether the regression residuals of a co-integrated relationship were stationary.

Equation 3.2 and 3.7 were estimated first by use of Maximum Likelihood Method and the residuals were estimated from the estimated equations. The values of the error term obtained were then tested for stationarity following the same procedure discussed in section 3.4.2 in this study. If these error terms were found to be stationary, thus  $I(0)$ , it meant that all the variables in the empirical model were co- integrated (thus there was a long-term equilibrium relationship among the variables). Alternatively, if the variables were  $I(d)$ , thus differenced of order `d` in order to be stationary, both the dependent and independent were co-integrated even though they were individually non-stationary. When this holds, then regression on levels was not spurious.

### 3.6 Error Correction Model

The Error Correction model (ECM), is an important innovation of time series econometrics. Even if co-integration was confirmed in the previous section, in the short-run, there might be disequilibrium between actual values of factor shares or energy shares and the long-run equilibrium values. The ECM was used to investigate the presence of equilibrium or disequilibrium between the short-run dynamics of factor shares and long-run equilibrium values of the same. The ECM which was first used by Sargan (1984) and later reformulated by Engle-Granger (1987) was used to examine the presence of equilibrium or disequilibrium between the short- run dynamics and long- run equilibrium.

The ECM was specified as:

$$\Delta S_{it} = a_0 + \sum_i a_i \Delta \ln X_{it} + \pi e_{t-1} + V_t \quad 3.14$$

Where  $X_i = P_K, P_L, P_E, Y, T$ ,  $\Delta$  is the first difference operator,  $V_t$  is the error term with usual properties,  $e_{t-1}$  is one period lagged value of the residuals from the levels estimated (from equation 3.2 and 3.8). All the variables were expressed in log form except the factor and energy shares. In specification 3.14,  $\Delta X_{it}$  captured the short-run disturbance in the independent variables. While,  $e_{t-1}$  was the error correction term (ECT) that captured the adjustment towards the long-run equilibrium. The coefficient of the ECT,  $\pi$  measured the speed of movement towards long-run equilibrium. In other words, if  $\pi$ , was significant, it showed what proportion of the disequilibrium in the factors in one period was corrected in the next period.

### 3.7 The Forecasting Power of the Inter-fuel and Factor Demand Models

One of the desirable properties of a model is that the estimated model should produce satisfactory prediction of future values of the dependent variable ( Koutsoyiannis ,1977). It was, therefore, necessary to test for the forecasting ability of the estimated models.

The forecasting performance of the estimated models was investigated using two approaches. First, differences between the actual (realized) and the predicted series were obtained. The smaller the differences between the actual values of the cost share and the predicted cost shares in total cost expenditure, the better was the forecasting performance of the factor demand model. Similarly, the smaller were the differences between the actual series and the predicted values of the particular form of energy, the better was the forecasting performance of the inter-fuel model.

The second method used to evaluate the forecasting performance of the estimated models was the computation of Theil's (u) inequality coefficient for each model. It was estimated by use of the following formula:

$$U = \sqrt{\frac{\sum (P_i - A_i)^2 / n}{\sum A_i^2 / n}} \quad 3.15$$

Where u was the square root of Theil's inequality coefficient,  $P_i$  was the predicted (forecast) change in the dependent variable, while  $A_i$  was the actual (realized) change in the dependent variable. This coefficient lies between zero and infinity (Kouttsoyiannis, 1977). The smaller the value of the coefficient, the better was the forecasting performance of the model.

### **3.8 Correlation Analysis and Detection of Multicollinearity**

Correlation analysis was done to investigate the degree of relationship between variables that appeared as explanatory variables in the models. It was important to do this in order to find out whether there was multicollinearity in the data or not. Multicollinearity here meant the presence of linear relationship among explanatory variables. Collinearity was indicated by a high value of the correlation coefficient. If the variables were collinear, this would have compromised the efficiency of the estimated parameters or made their estimation impossible.

Another approach of identifying the presence of multicollinearity was by following the processes given by Koutsoyiannis (1977). This involved gradually inserting additional explanatory variable into the model and examining their effects on the individual coefficients, on their student- *t* values and on the overall R squared. A new explanatory variable was classified as useful, superfluous or detrimental.

If the new explanatory variable improved the R squared, without giving wrong signs or values to the parameters, on a *priori* considerations, the variable was taken as useful and retained as an explanatory variable in the model. If the new explanatory variable did not improve the value of R squared and did not affect the values of the individual coefficients, it was considered superfluous and was removed from the empirical model. If the new variable affected considerably the signs and values of the coefficients, the variable was considered detrimental and was removed from the model.

### **3.9 Data**

This study used published data for the period 1970- 2005 focusing on the Kenyan manufacturing sector. The data used in this study were extracted from official publications including the Statistical Abstracts, Economic Surveys, Kenya Power and Lighting Company limited annual reports and Tariff booklets, the International Financial Statistics (IFS) and the Ministry of Energy's summaries of the petroleum sector data. From the above sources, the following information was extracted and recorded by use of data collection schedule in Appendix I.

The information obtained from these documents included: petroleum products sold to the sector of study in the study period, total sales to the industrial sector over the years, wholesale prices of petroleum products, electricity sales to the large commercial and industrial sector and the corresponding total revenue from electricity sales to this class of consumers. Also obtained from these documents were electricity tariffs and other costs incurred by the large commercial and industry in their consumption of electricity fuel, GDP contribution by the manufacturing sector, GDP deflator with 1995 as the base year, the Consumer Price Index (CPI) with the base year of 1995, annual real average wage rate per employee in the manufacturing sector, annual investment expenditure in the sector, real rate of interest of commercial bank loans, and the level of employment in the manufacturing sector over the years. The nominal data collected are presented in Appendix II (table A2).

### 3.9.1 Data Refinement

The data on specific energy types available from the above sources were not expressed in same units throughout the years. For example, electricity sales were in some years expressed in GWh and in other years expressed in KWh. Electricity sales were converted to the same units i.e KWh by use of 1GWh= one million KWh. This was done to allow analysis of the relationship between energy utilization and its determinants.

The sector's output and prices of energy were in nominal terms. To remove the effects of inflation, data on output were converted to real output by dividing the nominal value added by the GDP deflator using 1995 as the base year. The deflator was preferred because it is the most comprehensive price index for GDP ( Branson, 1989). This deflator, also correctly measured inflation since it is a weighted average of all the changes in prices of newly produced goods in the economy (Dernburg, 1985). For this reason, it had the advantage of taking into account all the newly produced goods allowing for changes in the composition of output.

The nominal prices of energy were converted to constant prices by dividing nominal energy prices by the consumer price index (CPI) with 1995 as the base year. This was done to avoid biased results caused by inflation. The CPI was chosen because it affects the manufacturer's expenditure on energy. The year 1995 was preferred as the base year because most of the macroeconomic variables showed normal performance during this year. The country was averagely stable during this year.

The price of electricity was available in categories, such as fixed charges, taxes, and tariff per KWh consumed. Because of this complexity, average electricity prices were estimated from

the tariff per KWh of the large commercial and industry class of consumers. Some of the years did not have figures for the tariffs; these were estimated by interpolation. To estimate total energy cost share function, total energy utilized by the sector in the sample period was needed. These were generated by converting each form of energy into tonnes of oil equivalent (TOE), using international conversion factors available in Appendix IV (Table A10). This allowed energy aggregation and estimation of the total energy function.

The refined data are presented in Appendix II (table A3).

### **3.9.2 Data Problems**

Data from the above records were not meant for a specific study. They were for general purposes. The data were not categorized into specific sectors to suit this study. Data on electricity sales were available in highly aggregated form, divided into consumer categories not according to economic sectors. There were no specific records on electricity sales to the manufacturing sector. Because of these problems, data on large scale commercial and industry were used as proxy for electricity consumption by the manufacturing sector. Also, data on some of the earlier years of the intended period of study (1970 -1974) for electric power use by the sector were not available. Data on this period were estimated by interpolation.

Data on petroleum products sales available in the records did not directly suit this study. There were no records on oil consumption by the manufacturing sector in the period 1970 –1993. Given that this was a long period, the study used the petroleum sales to industry as a proxy for petroleum consumption by the manufacturing sector.

There was a problem in obtaining the retail prices of the petroleum products over the years. The available records had prices of only a few products that included motor spirit, gas oil and

illuminating kerosene, leaving out other products some of which were heavily consumed by the manufacturing sector such as light and heavy diesel oil and fuel oil. Also, the reported retail prices were only applicable to Nairobi city. Because of this problem, the study used wholesale prices for the petroleum products reported at Mombasa.

Data were not available in the records on other sources of energy such as coal, solar, wind power, biogas and wood fuel. Some of these may have been consumed by the sector during the period of study, but since no records showed their utilization, they were assumed not to be among the fuels consumed by this sector, and were therefore dropped from the study. Therefore, the study only analyzed electricity and petroleum products.

Data on some of the variables that would have been useful to this study such as the energy using equipments and their corresponding prices were not available. Hence, these variables were dropped from the model.

### **3.10 Methods of Analysis**

The study analyzed the refined data using both descriptive and regression analyses. Regression analysis was done using Maximum Likelihood Method because of the nature of the model. This method was preferred because it assured that the estimates of the parameters were invariant to which equation was deleted.

Data were first converted to logarithms before testing for stationarity. Stationarity of the time series was tested using the unit root test. Co-integration test was done using the Dickey and Fuller two-stage procedure.

### **3.11. Determinants of Demand for Energy and their Expectations**

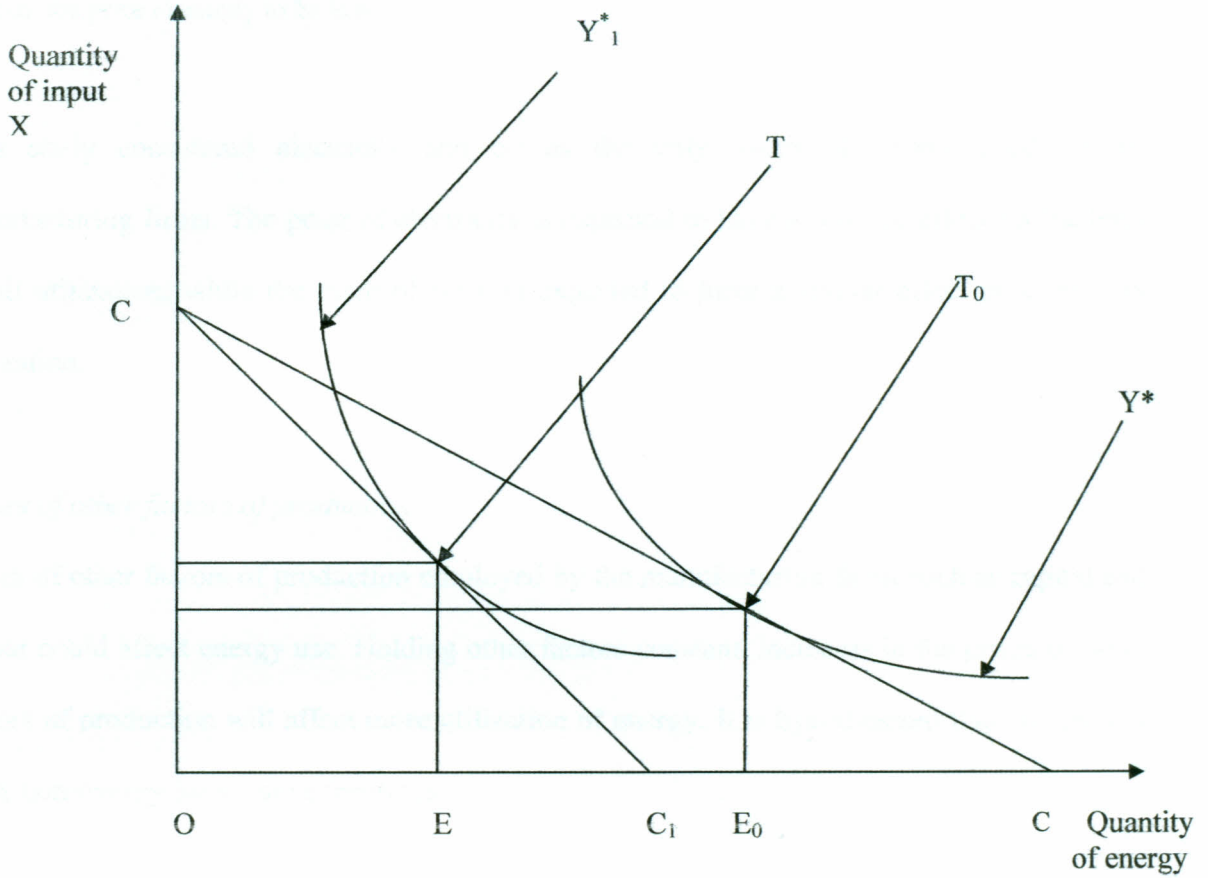
#### *Output*

Output is considered to be the most important determinant of energy consumption. Growth in the manufacturing sector measured by the value of output (income) is the main driving force behind growth in energy utilization by the firms. Past empirical evidence suggested that, there was a significant positive correlation between income and energy consumption. Therefore, a change in the firms' output was expected on a priori basis to increase utilization of energy, holding other factors constant. But with improvement in energy efficiency, it is also possible for the firms to utilize less energy for greater output levels.

#### *Energy Prices*

Economic theory suggests that for normal goods, factor prices are inversely related to respective quantities utilized. Assuming the price of energy increases while the price of other inputs remains constant, price change will induce adjustments and the firm will move from one equilibrium position to another as shown in Figure 3.1 that follows.

**Figure 3.1: Effect of increase of the price of energy**



In the original isocost line  $CC$ , the point of optimality is attained at point  $T_0$  at which  $E_0$  of energy is utilized. When price of energy increases, as indicated by a steeper isocost curve  $CC_1$ , the firm changes its input combination leading to new equilibrium position at point  $T$ . At  $T$ , less energy  $E$  is utilized and more of input  $X$  is used, and output declines from  $Y^*$  to  $Y^*_1$ . The total effect of the increase of the price of energy as indicated by the movement from point  $T_0$  to  $T$  is  $0E_0 - 0E$ . The effect of price increase of energy shows that the price of energy and the level of utilization are negatively related.

The study therefore, expects own price to negatively affect energy utilization. Also, given that energy is very important in the manufacturing process, and that very few substitutes exist in Kenya, the study expects the price elasticity to be low.

This study considered electricity and oil as the only forms of energy used by the manufacturing firms. The price of electricity is expected to have a positive effect on the level of oil utilization; while the price of oil was expected to have a similar effect on electricity utilization.

#### *Prices of other factors of production*

Prices of other factors of production employed by the manufacturing firms such as capital and labour could affect energy use. Holding other factors constant, increases in the prices of other factors of production will affect more utilization of energy. It is hypothesized that energy and other non-energy inputs are substitutes.

#### *Employment*

Employees affect energy use by the firms through their utilization of energy to produce goods and services and using transportation outside of the household. In-built is the labour productivity that determines GDP contributions of the sector and the need for energy for production processes. Holding other factors constant, as a firm increases its employment level, more output was expected hence greater demand for energy. The study expected energy utilization to increase with the increase of the level in employment of the manufacturing firms. However, this variable was dropped from the model because it was found to be insignificant in the factor demand functions.

### *Technology*

Technology is related to energy efficiency in determining energy utilization. Better machines and improvements in energy using equipment reduce the level of energy utilization. The assumption here is that as new technologies come to the market, the firms get the information and are able to afford and adopt them.

### *Price of Energy Appliances*

Expensive energy-using equipment reduces energy consumption. Energy use goes together with energy-using equipment. Holding other factors constant, whenever the prices of these equipments increase, the firms utilize the old stocks more effectively while demand for purchases of new equipment will decline leading to reduction in energy consumption. Time series data on prices of energy appliances were not available and therefore, the variable was dropped from the empirical model.

### *Structure of the Economy*

The relative importance of various sectors of the economy affects energy utilization. As structural changes occur in the economy, for example, expansion of the industrial sector, changes also occur in the demand for factors of production including energy. The overall change of energy use in the economy depends on whether the energy intensive industries are more dominant or not. Growth of more energy -intensive industries such as cement and steel manufacturing, use more energy than any other. Because of lack of data, this variable was dropped from the empirical model.

### *Energy Efficiency*

Energy efficiency refers to the ratio of value added by the manufacturing firms to the energy input utilized by firms. As new technologies and energy conservation measures are introduced to the manufacturing firms, holding other factors constant, the firms are expected to reduce their energy consumption (it is assumed here that firms adopt the new technology and energy conservation measures). With improvement in energy efficiency, it means that less energy is used to produce the same or more output. Through the use of step-wise regression analysis, this variable was found to lead to violation of the cost function restrictions. It was, therefore, dropped from the function.

## **CHAPTER FOUR**

### **EMPIRICAL FINDINGS**

#### **4.1 Introduction**

This chapter presents the findings of the study. It discusses the characteristics of the energy market in Kenya, the trends of the time series variables in the empirical model, correlation analysis, time series properties of the data, the results of the empirical model, and forecasting ability of the estimated model.

#### **4.2 Energy market in Kenya**

In section 2.5, the energy utilization model was developed assuming that the firms are price-takers in both input and output markets. The firms were assumed to minimize total cost of production subject to the target output. With changes in the factors that determine energy use, the firms were assumed to change to a new equilibrium point. The price of energy, value added, energy efficiency, technology, and employment were assumed on a priori to be affecting energy utilization in the Kenyan manufacturing sector. However, the Kenyan energy market is dominated by some features that might affect the achievement of optimality and thus making the analysis of the effects of changing conditions difficult (Kimuyu, 1988).

#### **4.3. Characteristics of Energy Market**

As discussed in chapter one, Kenya imports all its fossil (coal and petroleum) energy. For this reason, importation of fossil energy strains foreign exchange of the country. In this case, responses to changing conditions of energy demand are likely to be modified by budgetary inflexibilities. In addition, oligopolistic firms in the domestic oil and electric power sectors characterize the energy market. The major players in the oil sector in Kenya are the private

companies (Kenya Shell, Oilibya oil, Total oil, Kenol, Kobil oil and Caltex oil ) and the government. In addition, there are other smaller private companies ( Elf, Fulex, Galana, Gapco, Jovenna, Nock and Masefield, and Engen) whose market share is about 5 per cent. In the electricity sector ,there are the, KPLC, KENGEN, IPP and EPP.

The private firms in the oil sector and the government are greatly involved with the importation, storage, refinement, distribution and setting of prices of petroleum products. In the electricity sector, the private and semi-private companies deal with generation, distribution and marketing. KENGEN is the major producer of electricity, supplemented by the IPP and EPP. KPLC is responsible for the distribution and marketing of electricity. In addition there is the Energy Regulatory Commission (ERC) whose major roles include review and adjustment of consumer tariffs among others. It is possible that all the above combined may lead to continuous disequilibrium in the domestic energy market.

Second, large public corporations, industries and few large private firms which dominate the energy sector in Kenya in terms of supply and distribution as discussed above, means that energy prices used in this study may not have been determined by the forces of a free market. For example, since the deregulation of the petroleum prices in 1994, the government has put an indirect subsidy on domestic kerosene through lower taxes. This means that the prices charged on kerosene are not determined by forces of demand and supply. Electricity prices are set administratively according to the supply cost, including all fuel used to generate it and operating and maintenance costs as well as recovery of construction costs and a reasonable profit.

Third, the Kenyan economy has been changing. There has been growth of energy intensive industries such as cement industry (Bamburi is a good example), and steel manufacturing, which may be hard to capture in a theoretical model. Also in the energy utilization, there have been quantum jumps in its usage due to increase of supply and distribution of energy especially to the rural industries. There is rural electricity programme under KPLC where the aim is to reach rural areas in terms of electricity access to develop the rural areas among other objectives. There have also been reforms in the energy sector introduced by the government between 1994 and 2000. These reforms include, commissioning the IPP and EPP discussed in chapter one of this study, permitting private sector in the supply and marketing of oil, and deregulation of energy prices (especially the petroleum products prices) among others.

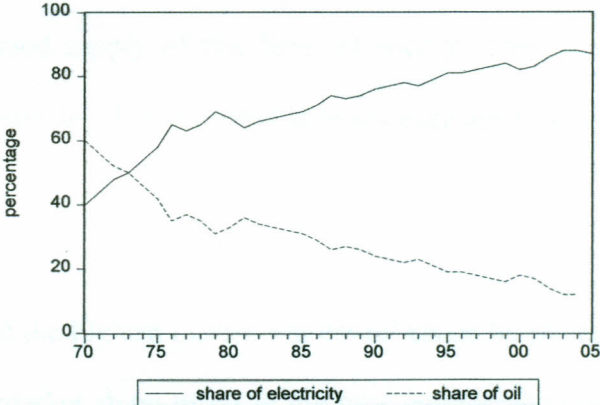
All the above features of energy market in Kenya, do significantly affect energy utilization but since it was difficult to assess their effects on energy demand, the study did not incorporate them.

#### **4.4 Energy Utilization in Kenyan Manufacturing Sector**

In Kenya, both commercial and traditional energies are consumed. The commercial forms of energy mainly include petroleum products and electricity. Wood fuel (firewood and charcoal) is the main energy source in the traditional sector. The formal sector, which comprises commerce, industry and the urbanized communities, largely depends on fossil fuels and electricity. The manufacturing sector in Kenya was found to be using mainly electricity and oil as their main sources of energy. There were no records of usage of traditional forms of energy in this sector.

Sample data revealed that the manufacturing sector on average utilized relatively more electric energy compared to oil fuel (see Figure 4.1). The share of each form of energy in the total energy market are provided in appendix II (TableA6).

**Figure 4.1: Energy utilization in the manufacturing sector 1970-2005**



Source of original data: Republic of Kenya. *Economic Survey*. Various issues. Nairobi: Government Printer.

During the earlier years of the sample period (1970-1972), oil use by this sector in terms of total energy use exceeded the quantity of electricity consumed. This could be attributed to inadequate supply of electricity caused by low generation. After 1973, the trend of electricity in this sector consistently slopes upwards, while use of oil trends downwards, on average.

The share of electricity in total energy utilized in the manufacturing sector increased from 40 per cent to 87 per cent between 1970 and 2005, while the share of oil declined from 60 per cent to 13 per cent during the same period. The sector is seen to have progressively used more electricity than oil in the sample period. The dominance of electric fuel over oil energy could

be attributed to its cost, availability, the energy policy and its advantages over oil, such as being clean and friendlier to the environment.

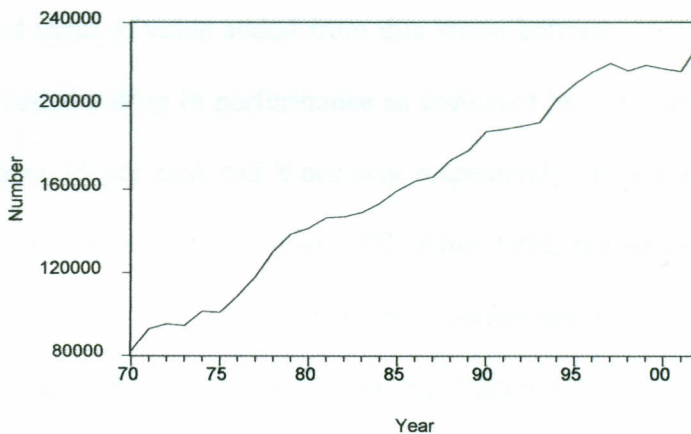
Apart from the 30MW from Uganda, most of the electricity is generated locally while oil is wholly imported, making electricity much cheaper compared to oil. The Kenyan government has introduced reforms in the energy sector (as discussed in chapters one and two), which have, over time increased supply of this form of energy. This, coupled with the policy of increasing energy accessibility, has contributed to the ever-upward trend in electric fuel use by the sector.

The year 1981 recorded the highest increase in the oil usage by the manufacturing sector over the study period. The market share of oil in the total commercial energy basket in the sector studied increased from 41782 TOE to 49697 TOE, an increase of 19 per cent, while electricity usage increased from 83061 TOE to 88220 TOE in the same period, an increase of 6 per cent. The year 2000 showed an increase of oil use by 13 per cent while electric demand declined by 0.8 per cent. Low water volumes caused by severe drought that the country experienced between 1999 and 2000 reduced power production leading to rationing that affected the level of utilization of electric energy by this sector. In the year 2002, consumption of electric fuel picked up as recorded by an increase of 2.8 per cent from 188650 TOE to 193895 TOE, while oil use reduced from 38224 TOE to 39979 TOE. This was attributed to increase in hydro-electricity production caused by heavy rains experienced during this period. On average, the energy share markets suggest that over time, the manufacturing firms will keep on reducing the quantity of oil used in their production processes, while use of electricity will be trending upwards.

## 4.5 Trends of the Determinants of Energy Utilization

Figure 4.2 shows wage employment of the manufacturing sector in the period under study. Number of wage employees in the manufacturing sector was assumed as one of the explanatory factors in energy use. This variable was, however, dropped from the estimated equations because it was found to be non-significant. Wage employment shows dramatic growth up to 1998 when there was a slight decline up to the year 2001. Between 1997 and 2001, employment declined from 220484 persons to 216600 persons. This decline was attributed to the general poor economy-wide performance.

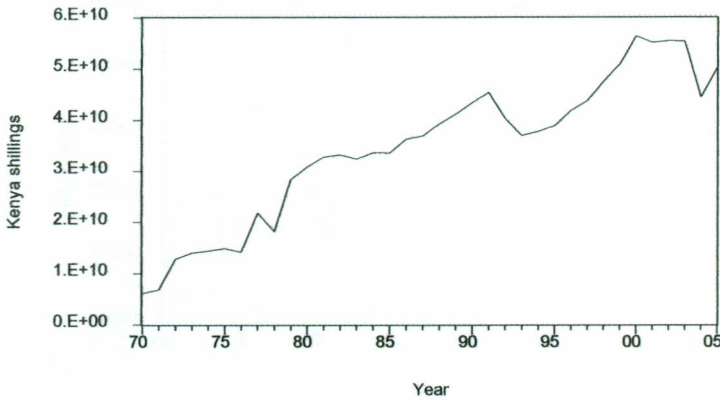
**Figure 4.2: Wage employment in the manufacturing sector 1970-2005**



Source of original data: Republic of Kenya. *Economic Survey*. Various issues. Nairobi: Government Printer.

GDP growth rate declined from 2.4 in 1997 to 1.8, 1.4, -0.2 percent in 1998, 1999 and 2000, respectively. From the year 2002 to 2005, employment increased by about 7 percent. This could be attributed to the improvement of the economy. Figure 4.3 shows the real value added series over the study period.

**Figure 4.3: Real value added in the manufacturing sector : 1970-2005**

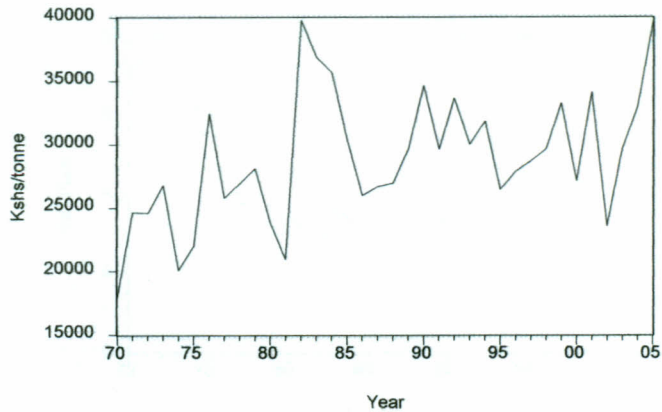


Source of original data: Republic of Kenya. *Economic Survey*. Various issues. Nairobi: Government Printer.

Value added was one of the determinants of energy use in the manufacturing sector. There was generally an upward trend of value added from this sector between 1970 and 1991. The years 1992 and 1993 recorded a drop in performance as indicated by reduction of real value added of the sector by about 11 per cent and 8 per cent respectively. This may be attributed to the effects of elections that were carried out in 1992. After 1992, the sector picked up again the positive trend until 2001 when it recorded poor performance of negative 2.2 per cent, attributed to drought and subsequent power rationing. Figure 4.4, shows the trend of real price of oil over the period of study.

As the price of an alternative source of energy to electricity, the price of oil was assumed to determine use of electricity. The real price of oil shows an erratic trend. It is difficult to predict the price of petroleum products at any particular time. In the year 1973, the real price of oil decreased from Ksh. 26780 per tonne to KShs 20085 per tonne, a decline of about 25 per cent. In the year 1975, the trend reversed.

**Figure 4.4: Average real price of oil : 1970-2005**

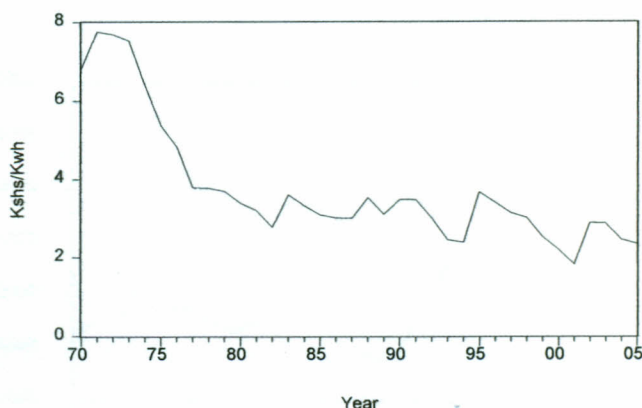


Source of original data: Republic of Kenya. *Statistical Abstract*. Various issues. Nairobi: Government Printer.

There was an increase in the price of oil of about 48 percent between 1975 and 1976. This can be attributed to the oil price shock of 1974 whose effects were still being felt in the year 1976. Oil prices are determined by the events in the international oil market, which keep on fluctuating depending on the conditions of supply and demand. A sharp increase is observed in the year 1982 of 90 percent from 20,941 shillings per tonne in 1981 to 39,797 shillings per tonne in 1982. The coup *d'état* attempt of 1982 and the effects of drought of 1980s could be responsible for this outcome. After 1982, the price of oil showed unpredictable trend until 2002 when there was a sharp decline from Kshs.34130 per tonne in the previous year to Kshs 23553 per tonne. Increase in supply of electric power (from 2167 GWh to 2278 GWh) during this year may have reduced the demand for oil leading to a reduction in its price. Figure 4.5 shows the trend of the price of electric energy over the study period.

The real price of electricity as seen in figure 4.5, recorded a downward trend from 1970 to 1982. After 1982, it followed an unpredictable trend up to the end of the study period.

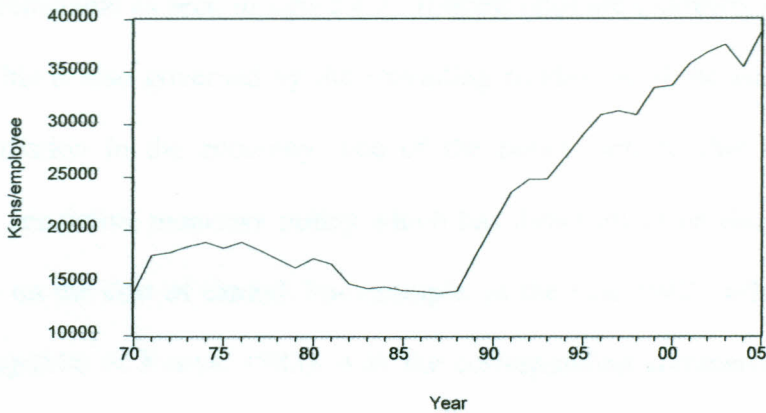
**Figure 4.5: Average real price of electricity 1970-2005**



Source of original data: Own calculations.

This can be attributed to weather conditions since most of the electricity produced in Kenya is hydro. Between 1970 and 1973, the real price of electricity increased by about 10 per cent. A sharp increase is observed in the year 1995 when the real price increased from about Kshs. 2.37 to 3.8 per KWh. Between 2002 and 2005, the price of electricity ranged between 2.8 and 2.3 shillings per Kilowatt hour. What is unique about the price of electricity is that it remained fairly constant for sometime until weather changed especially due to drought conditions, when production of thermal electricity increases. During this period, the price of this form of energy increased because plenty of oil was used by the electricity sector to generate thermal electricity. Given that oil is wholly imported, to recover the foreign exchange spent and the cost of many generators used, the price of electricity had to increase to reflect these costs. Figure 4.6 shows the trend of average real earnings of employees that was used as the price of labour in the manufacturing sector over the study period.

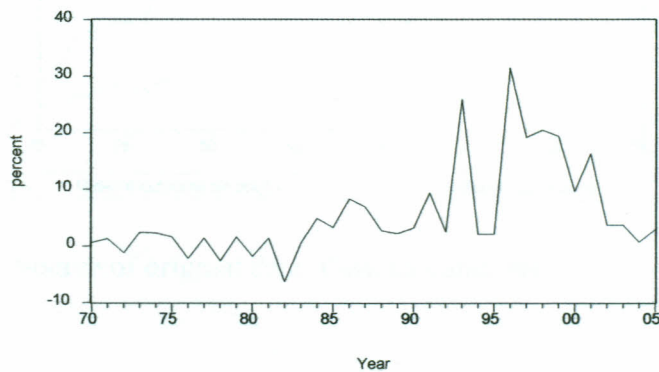
**Figure 4.6: Average annual real wage earnings per employee in the manufacturing sector 1970-2005**



Source of original data: Republic of Kenya. *Statistical Abstract*. Various issues. Nairobi: Government Printer.

Generally from the year 1970 to around 1988, the average real wage earnings were declining. Annual wage earnings declined from Kshs17622 in 1971 to Kshs 14204 in 1988. After the year 1988, there was a steady increase in real wage earnings per employee up to the end of the study period. Figure 4.7 shows the real interest rates of commercial banks loans that were used as the proxy variable for the price of capital in this study.

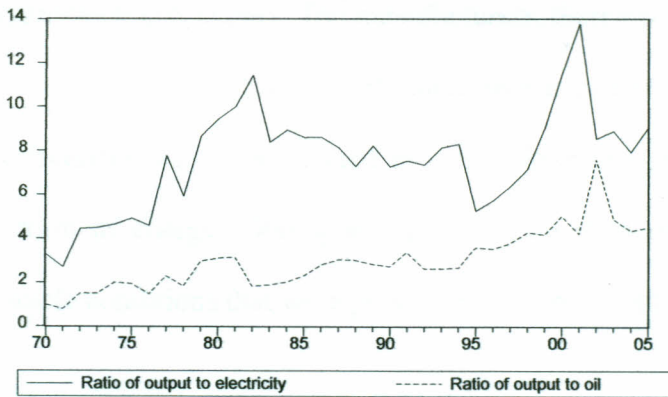
**Figure 4.7: Real interest rates of commercial bank loans 1970-2005**



Source of original data: Republic of Kenya. *Economic Survey*. Various issues. Nairobi: Government Printer.

The trend of real interest rates of commercial bank loans in Kenya in the study period was found to be unpredictable as seen in figure 4.7. Interest rates are indirectly determined by the Central Bank. This is also governed by the prevailing conditions of the economy. Whenever there is high inflation in the economy, one of the policy options that the Central Bank implements is a restrictive monetary policy which has direct effect on the commercial bank loans and hence on the cost of capital. For example, in the year 1982, inflation rate stood at 22.3 percent (Republic of Kenya, 1983), with the corresponding commercial bank loan real interest rate being negative 6.3 percent. In the year 1992 when inflation rate was recorded to be 27.5 percent, the cost of borrowing bank loan was at 2.5 percent. High interest rates for obtaining commercial bank loans act as a dis-incentive to investment. Figure 4.8 shows the trend of energy efficiency (value added divided by energy used by the firms) over the study period.

**Figure 4.8: Energy efficiency in the manufacturing sector 1970-2005**



Source of original data: Own calculations

Energy efficiency was taken to be one of the factors influencing energy use in the sector of study. This variable was, however, dropped from the estimated functions because it led to the

violation of the restrictions imposed on the cost model. On average as shown in figure 4.8, efficiency in oil use has been increasing over the study period and has remained less than the efficiency in electric power use. This suggests that over the period of study, the manufacturing firms on average have been increasingly using less oil in their manufacturing processes

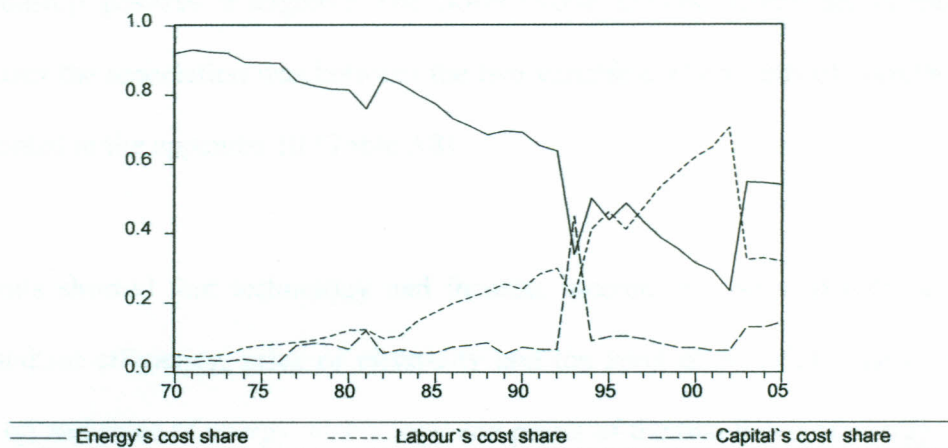
Use of oil fuel is one of the major contributors to environmental pollution, and that efficiency in energy has positive effect on the competitiveness of Kenyan manufactured goods. This ratio (output/energy) ranged between 0.98 and 13. The data suggest that the sector to some extent implemented oil conservation measures over the study period.

Efficiency in use of electricity increased between 1970 and 1982 after which it declined up to the year 1995, only to rise again up to the year 2001 followed by a decline to the end of the sample period. The year 2001 recorded the highest increase in electricity efficiency, an increase of 19 percent. This is the period when the country experienced serious drought that led to reduction of hydroelectricity supply. The manufacturers, therefore, had to utilize electric power more efficiently. Between 2001 and 2005, there was a general decline of electricity efficiency. The manufacturers may have relaxed in using electricity more efficiently due to high supply of this form of energy. During this period generation of hydroelectricity had increased due to favorable conditions that were present within the country.

#### **4.6 Share of Energy and Other Non-energy Inputs in Total Cost of the Manufacturing Firms**

Figure 4.9 shows the cost shares over the sample period. Cost shares were used as the factor demands in this study.

**Figure 4.9: Factor cost shares: 1970-2005**



Source of original data: Own calculations

The share of energy in the total cost of production of the manufacturing sector experienced a steady decline over the sample period while that one of labour increased. The share of energy cost was seen to be above all others from the year 1970 to around 1998 when labour cost share overtook it. The share of capital generally remained constant over the sample period except between the years 1992 and 1994 when it experienced a sharp increase. All the three factors experienced a shock during this period.

This is the period when the country had the first multiparty elections which was characterized by ethnic violence that affected all the macroeconomic variables including energy, labour and capital. During 1994, the energy sector had started implementing reforms that may have affected its supply, generation and distribution.

#### **4.7 Correlation coefficients**

Correlation analysis was done to find the degree of association among variables and also to find out whether the data had the problem of multicollinearity. Simple correlation coefficients

showed the strength of relationship between two variables and they also showed the direction of relationship, positive or negative. The closer to one, the coefficients are in absolute terms, the stronger the association was between the two variables. The results of correlation analysis are presented in the appendix III (Table A8).

The results showed that technology and income, income and price of electricity, price of labour and oil efficiency, price of electricity and the level of electricity used in the sector, price of oil and price of energy, technology and prices of the two forms of energy, income and the level of energy used in this sector were highly correlated. There is almost a one to one (at least 0.90) relationship between income and technology, income and electricity, income and energy, income and oil efficiency, technology and electricity, electricity and energy, and electricity and oil efficiency. If such highly correlated variables appear as explanatory variables in the same equation, one is likely to get non-unique estimates of the parameters. Technology and output were both explanatory variables in all equations estimated. The study tolerated these variables as explanatory variables in the same equations since the problem did not affect seriously the estimates of the coefficients (Koutsoyiannis, 1977). However, the variable energy efficiency was dropped from the function because it was found to lead to violation of the cost restrictions of linear homogeneity.

#### **4.8 Stationarity Test Results**

To examine whether the series were stationary or not, ADF unit root test was conducted on variables at levels with intercept and trend. Visual inspection of figures 4.1 to 4.9 in this chapter, suggests that the variables in the model were non-stationary. Figure 4.9 in particular suggested that all dependent variables in the translog function experienced structural break between 1992 and 1994. This was due to the effects of multiparty elections of 1992. Value

added and price of electricity showed consistent upward and downward trends, respectively. Thus, their means and variances kept on changing over the study period. To find out whether the time series were stationary or not, the study first conducted the unit root tests of the series at log levels for most of the variables using the standard ADF unit root test. The cost shares series were not expressed in logs, the same applied to the cost of capital because of the nature of its values some of which were negative. The ADF unit root test was done by estimating equation 3.13 by use of OLS whose results are presented in table 4.1.

**Table 4.1: Augmented Dickey Fuller unit root test of the variables at levels**

Variable	Lag	ADF statistic	
		Levels	First difference
Price of electricity	1	-2.73	-5.09
Price of oil	1	-3.77	
Price of labour	1	-1.85	-3.11
Real value added	1	-3.8	
Interest rate	1	-2.56	-7.40
Employment	1	-1.2	-3.9
Total energy	1	-1.7	-4.8
Oil	1	-0.5	-7.5
Electricity	1	-2.28	-3.17
Electricity cost share	1	-3.10	-4.96
Oil cost share	1	-3.10	-4.96
Cost share of total energy	1	-1.74	-4.28
Cost share of labour	1	-1.97	-4.46
Cost share of capital	1	-3.8	

Source: Own Calculations.

Note: The critical value of the ADF statistic (with constant and time trend) was  $-3.55$  at 5 percent for both level and at first differences of the variables. All variables were expressed in natural log form except the price of capital.

As shown by the ADF, with exception of the price of oil, real value added and cost share of capital, the study failed to reject the null hypothesis that the log levels of the series were non-stationary. Price of oil, real value added and the cost share of capital were the only variables that were found to be stationary at levels. The rest of the variables were statistically non-stationary at 5 per cent levels. The price of labour and the amount of electricity used were found to be  $I(2)$ . These meant that they needed to be differenced twice for them to attain stationarity.

The rest of the variables that were not stationary at levels (price of electricity, employment, interest rate, total energy and types of energy series) were  $I(1)$ , thus they needed to be differenced once for them to achieve stationarity. The interest rates that are determined by the conditions prevailing in the economy, keep on changing from time to time.

Holding other factors constant, as the manufacturing sector kept on expanding, the demand for labour increased making average level of employment and its variance to change with time. Total energy (oil and electricity) was also non-stationary which was similar to individual forms of energy. The variables therefore satisfied the necessary condition for testing for co-integration.

#### **4.9 Inter-fuel Results**

Some of the objectives of the study were to identify the determinants of energy utilization in the manufacturing sector, estimate the energy demand functions and estimate the degree of substitution among energy forms. In this section, the results of these objectives are presented

and discussed. Two separate energy demand models were estimated, one for electricity and another one for oil fuel.

The study estimated the inter-fuel translog cost model (3.9) subject to the appropriate restrictions (3.10), from the Kenyan manufacturing data for the period 1970-2005. The model was estimated using the Maximum Likelihood Technique. Before accepting the results of the inter-fuel translog model, several diagnostic tests were carried out which are shown in Table 4.2. The results passed most of the diagnostic tests as shown in the table.

The Jarque-Bera statistic for testing normality of the residuals was 0.82 with probability of 0.66. Therefore, the hypothesis of normality of the residuals of the inter-fuel model was not rejected at 5 per cent level. The estimated residuals therefore, had a normal distribution.

The ARCH residuals had a value of 0.27 and probability of 0.86, so the assumption of homoscedasticity was not rejected.

**Table 4.2: Diagnostic tests for the inter-fuel model**

$S_i$	Jarque-Bera	LM Test (lag 3)	Chow forecast test from 1992	ARCH Test (lag 3)	Ramsey RESET Test	D.W
Electricity	0.82(0.66)	1.99(0.140)	4.27(0.004)	0.27(0.86)	6.8(0.0146)	1.144
Oil	0.82(0.66)	1.99(0.140)	4.27(0.004)	0.27(0.86)	6.8(0.0146)	1.144

Source: Own calculations

$S_i$ =Share of energy type  $i$  in total energy cost. Figures in parentheses represent probabilities.

The Chow forecast test for structural break in the year 1992, had an F –Statistic value of 4.27 and a probability of 0.004 suggesting that there was no structural break in the inter-fuel model before and after 1992. The Durbin Watson test statistic had a value of 1.144. This value was not close to zero suggesting mild autocorrelation in the residuals. Since the estimated parameters were unbiased, the study tolerated this problem.

Due to specification errors such as omission of variables, incorrect functional form and correlation between the explanatory variables and the error term, which can lead to non-zero error term vector (Gujarati 1995; Johnson and Dinardo, 1997) the Ramsey RESET test was performed. The test was done to find out whether there were any specification errors in the inter-fuel model. The results showed probabilities of 0.0146 implying that there was no significant evidence of mis-specification of the model.

The F- statistic was used to test the null hypothesis that all the slopes were equal to zero. In other words, this test was meant to investigate whether all the explanatory variables ,as a group, influenced oil and electricity utilization as dependent variables. The F- statistic had a value of 42 with probability of zero for both functions, which led to the rejection of the null hypothesis that all coefficients were equal to zero. The corresponding adjusted R squared was different from zero. Figures A1 (see appendix V) show the graph obtained by plotting the scattered points of the actual and predicted values of electricity. Similarly, figure A2 shows the graph obtained by plotting the scattered points of the actual and predicted values of oil. The Residual graphs are also shown in the same graphs. The estimated models were seen to track the data well as the predicted and actual values were very close.

These plots were also used to test for forecasting ability of the estimated model. If the model experienced structural changes during the sample period, its forecasting performance should deteriorate. From the figure, the forecasting performance of the model was good in the entire sample period. The inter-fuel model was, therefore, stable in the entire sample period. Overall, the diagnostic results were satisfactory for the inter-fuel model since it passed most of the diagnostic tests. Table 4.3 presents the results of the inter-fuel translog cost model.

**Table 4.3: Parameter estimates of the share models (inter- fuel)**

Parameter	Parameter estimate	t-statistic
Constant for electricity model	-0.204	-0.29
Price of electricity in the electricity model	0.179	6.67*
Price of oil in the electricity model	-0.193	-6.56*
Price of labour in the electricity model	0.053	1.83
Price of capital in the electricity model	-0.001	-1.81
Output in the electricity model	0.066	3.151**
Technology in the electricity model	0.007	4.31**
Constant for the oil model	1.204	1.70
Price of electricity in the oil model	-0.179	-6.67*
Price of oil in the oil model	0.193	6.56*
Price of labour in the oil model	-0.053	-1.83
Price of capital in the oil model	0.001	1.81
Output in the oil model	-0.066	-3.15**
Technology in the oil model	-0.008	-4.31**
Droughts of years 1980, and 2000 and the 2003 U.S.A's military attack on Iraq (for electricity model)	-0.034	-2.04**
Droughts of years 1980, and 2000 and the 2003 U.S.A's military attack on Iraq (for oil model)	0.034	2.04**
Adjusted R-squared(Electricity)	0.89	
Durbin-Watson stat (Electricity)	1.144	
R-squared(Oil)	0.91	
Adjusted R-squared(Oil)	0.89	
Durbin-Watson stat (Oil)	1.144	

Source: Own calculations

\*, \*\* denotes significant at 5 percent and 10 percent respectively. All variables are expressed in natural logs except price of capital.

The inter-fuel results were good as shown by the value of the adjusted R-squared (0.89) and the number of significant coefficients. About 89 percent of the changes in the shares of electricity and oil in the total fuel expenditure respectively were explained by the changes in the explanatory variables included in the inter-fuel translog model. Significant cross-price relationships existed between oil and electricity.

Each fuel share significantly responded to own price changes. Apart from own prices, output, technology and unexpected events were found to significantly determine the shares of the energy components in the total fuel expenditure. Increases in the firm's output leads to significant increase in use of electricity while it reduces demand for oil. The results suggest that there were significant economies in the use of oil as fuel, e.g. if income increased by one percent, the share of oil in the total fuel expenditure falls by 0.07 percent. The unexpected events that affect the energy utilization include countrywide drought that affected Kenya in 1980 and 2000 that led to the shortage of hydroelectricity, and the 2003 US led military invasion in Iraq that led to prices of crude oil increasing by 11.1 per cent from US \$ 27 per barrel in December 2002 to US \$ 30 per barrel in 2003. The influence of technical change was found to significantly encourage use of electricity and discourage use of oil in the Kenyan manufacturing sector.

Table 4.5 presents estimates of own, Allen ( $A_{ij}$ ) and cross elasticities ( $E_{ij}$ ) of the share equations (inter-fuel) computed at the mean values in the period 1970-2005 available in Table 4.4. These estimates were derived using the equations 3.4- 3.6 in this study, and based on the parameter estimates contained in table 4.3 above.

The Allen elasticity is a share- weighted cross-price elasticity that measures the proportionate change in relative factor shares induced by proportionate changes in relative price of factors. The cross-price elasticity is a more useful measure for policy purposes since it measures the proportionate change in amount of factor use induced by a proportionate change in the price of the other factor.

**Table 4.4: Mean cost shares**

Mean cost shares for the total cost function			Mean energy cost shares	
Capital	Labour	Total energy	Electricity	Oil
0.080852	0.255481	0.663667	0.280130	0.719870

Source: Own calculations.

**Table 4.5: Own Price Elasticities**

Elasticity	Estimate
Electricity own price	-.082
Oil own price	-0.013
Allen cross price	0.045
Electricity cross price	0.032
Oil cross price	0.032

Source: Own calculations

The study expected own price elasticities to be negative and inelastic. The results presented in table 4.5 show that own price elasticities have the expected signs. However, the absolute values of own elasticities are small but statistically significant at 5 percent level. With one per cent increase in the prices of electricity and oil, their utilization *ceteris paribus* decreases by 0.082 and 0.013 per cent, respectively. These values suggest that utilization for electricity and oil are price inelastic. In other words, the demand for both of the energy components has very

low response to their respective price changes. With an increase in electricity price or the price of oil, the manufactures reduce their use of these two forms of energy by a smaller percentage than their respective price increase. Such inelastic estimates for energy are intuitively plausible for a relatively energy scarce country like Kenya. The country does not have enough own locally available source of energy. The locally generated electricity does not satisfy the demand and the country does not have local sources of oil, but depends wholly on oil imports whose price is controlled by the international oil market. There are no major energy substitutes hence the insensitivity of the sector to energy price changes. Energy is also a key input the manufacturers cannot do without even when energy prices increase.

The value obtained of own price elasticities falls in the range of those previously found by other researchers such as Lin (2003) Chishti and Mahmud (1990), and Kimuyu (1988), who obtained electricity price elasticity to be  $-0.032$  ,  $-0.1144$ , and  $-0.161$  and respectively. The policy implication of these results is that energy price alone cannot achieve much in controlling the future use of electricity and oil in the Kenyan manufacturing sector.

The results in table 4.5 for cross price elasticities suggest that there are significant substitution possibilities between the types of energy utilized by the manufacturing sector. Electricity and oil were found to be substitutes. This is also confirmed by the estimated Allen–Uzawa cross price elasticity that was found to be  $0.045$ . However the substitution possibility was very low  $0.032$ . This means that a 1 percent increase in the price of oil given the price of other factors, will lead to a  $0.032$  percent increase in the relative share of electricity in the total fuel expenditure. Similarly, a 1 percent increase in the price of electricity given the price of other factors will lead to  $0.032$  percent increase in the relative share of oil. Generally, it seems that there has been little inter-fuel substitution in the manufacturing sector in Kenya. Substitution

between oil and electricity is practically impossible without major modifications to the stock of capital, especially where lighting and appliances are concerned. Other previous studies have found similar low substitution possibilities between various forms of energy in absolute terms. Mahmud and Chishti (1990) found cross price elasticities ranging between 0.13 and 0.4 in absolute terms, and that electricity and oil were substitutes. Mahmud (2000) found also that electricity and oil are substitutes with the cross price elasticities ranging from positive 0.00787 to 0.144. In contrast to these findings, other studies showed that oil and electricity were complementary (see for example, Christopoulos, 2000).

The conclusion for this part of estimation is that oil and electricity are substitutes in the manufacturing sector and that own price, value added, technology and unexpected events such as drought, influence utilization of these two forms of energy over the study period.

#### **4.10 Results of the Aggregate Model**

This section presents the results of the aggregate model.

Among the objectives of this study were to identify the determinants of energy utilization in the manufacturing sector, estimate the energy demand model, and estimate the degree of substitution among total energy and other non-energy inputs. This section presents and discusses the estimation results.

In the second stage of estimation, the aggregate model consisting of equation 3.2 was estimated using the estimated values of  $P_E$  (total energy price index) as an instrument from equation 3.7 and subject to the restrictions of 3.3. Before accepting the results, various diagnostic tests were carried out. Table 4.6 presents the diagnostic results of the total cost

share equations. The estimated total cost share equations passed almost all diagnostic tests and therefore, the estimated cost share equations are econometrically sound.

**Table 4.6: Diagnostic tests of the total cost share equations**

$S_i$	Jarque-Bera	LM Test (-2)	Chow forecast test from 1999	ARCH Test (-3)	Ramsey RESET	D.W
Energy	0.34(0.84)	3.65(0.026)	3.34(0.014)	0.94(0.43)	4.15(0.05)	1.20
Labour	3(0.22)	2.05(0.13)	10(0.00007)	0.27(0.84)	7.3(0.011)	1.45

Source: Own calculations

Figures in parentheses represent probabilities

The Jarque -Bera statistic for testing normality of the residual are 0.34 and 3 for energy and labour cost share equations respectively. The corresponding probabilities are 0.84 and 0.22. The residuals of both the energy and labour demand equations are therefore normally distributed at 5 per cent level. The ARCH residuals have values of 0.94 and 0.27 for energy and labour, respectively. The corresponding probabilities are 0.43 and 0.84; the assumption of homoscedasticity was not rejected.

The Chow break point test for testing the stability of the coefficients before and after 1999 has F statistic values of 3.34 and 10, for energy and labour, respectively. These suggest that there was no structural break in the energy and labour demand models before and after 1999. The Ramsey RESET test for mis-specification of the translog function has an F- statistic values of 4.15 and 7.3 for energy and labour demand functions. Their corresponding probabilities of 0.05 and 0.01 suggest that there is no significant evidence of mis-specification of the two functions.

The F statistic test was also carried out to find out whether all the explanatory variables as a group for each demand model determine the demand for energy and labour, respectively. These statistics had values of 83 and 33 with p-value probabilities of zero for each. These findings led to the rejection of the null hypothesis that all the slopes were equal to zero. Therefore, all the explanatory variables as a group for each model, significantly influenced the demand for energy and demand for labour. This also suggested that the adjusted R squared for both models were significantly different from zero.

The graphs A3 and A4 (see appendix V) of the actual observations and the fitted values and the regression residuals of the cost share equations showed that the estimated model tracked the data well. These plots were also used to test for forecasting ability of the estimated model. If the model experienced structural changes during the sample period, its forecasting performance should deteriorate. From the figures, the forecasting performance of the model was good and therefore, the model was stable over the period under study. The parameter estimates of the total translog cost function are presented in table 4.7.

These equations were also estimated using the Maximum Likelihood Method. To avoid singularity, the capital share equation was dropped from estimation but its parameters were estimated from the restrictions 3.3.

The value of the adjusted R squared (0.93) was good as it suggested that 93 percent of the changes in the cost shares of energy and non-energy factors in the total input expenditure in the manufacturing firms were accounted for by the explanatory variables included in the share equations.

**Table 4.7. Parameter estimates of translog total cost model for the Kenyan manufacturing sector with energy price as an instrument**

Parameter	Parameter estimate	T-statistic
Constant for the total energy model	1.8293	1.25
Price of capital in the energy model	-0.007341	-5.46*
Price of labour in the energy model	-0.05081	-0.79
Price of energy in the energy model	0.08914	3.2415*
Output in the energy model )	-0.09256	-1.96**
Technology in the energy model	-0.0086	-2.53*
Constant for the labour model	-1.6793	-0.83
Price of capital in the labour model	0.004104	2.22*
Price of labour in the labour model	0.0974	1.10
Price of energy in the labour model	-0.09627	-2.5*
Output in the labour model	0.1144	1.76
Technology in the labour model	0.005290	1.13
Constant for the capital model	0.8499	0.48
Price of capital in the capital model	0.00324	1.98**
Price of labour in the capital model	-0.04657	-0.59
Price of energy in the capital model	0.007134	0.21
Output in the capital model	-0.02189	-0.38
Technology in the capital model )	0.003313	0.80
Dummy D=1 for the years 1985,2002 and =0 if otherwise	-0.2037	-4.72*
Adjusted R squared (Energy)	0.93	
Adjusted R squared (Labour)	0.84	
Durbin Watson(Energy)	1.2	
Durbin Watson (Labour)	1.45	

Source: Own calculations

\*, \*\* denotes significance at 5% and 10% respectively. All variables are expressed in natural logs except the price of capital.

Own price, technology, value added, price of capital and unexpected events were found to significantly affect utilization of energy in the manufacturing sector. Technical changes were found to lead to reduction in energy use. Improvement in technology is, therefore, welcome in the manufacturing sector since it leads to energy saving as was expected in the study.

Droughts and subsequent power rationing whose effects were still being felt in 1985, and the multiparty elections (2002) seem to have significantly affected the utilization of the factors of production in the manufacturing sector as evidenced by the t-statistics (-4.7, 3.45, and -2.77) of the dummy variable coefficient in the three share equations. Table 4.8 presents the own price elasticities calculated at the mean values of the cost shares available in table 4.4. These elasticities were estimated using the formulae presented earlier in equations 3.4-3.6.

**Table 4.8. Own price elasticities of demand for inputs in the Kenyan manufacturing Sector**

	Own price demand elasticity
Labour	-0.364
Capital	-0.88
Total energy	-0.20

Source: Own calculations

All the own price-elasticities take the expected negative signs. The demands for total energy and labour were own price inelastic. The price elasticity of total energy was the smallest (-0.20) in absolute terms compared to all factors own-price elasticities. This suggested that energy utilization within the manufacturing sector was least sensitive to own-price changes as compared to price sensitivities of other inputs of production utilized in this sector. With a 1 percent increase in the price of energy, given the price of other factors, its demand declines by 0.20 percent. Given that energy is an essential input in the manufacturing process and that not enough energy substitutes exist in Kenya, the low price elasticity was expected. Other reasons for the low energy response to own-price changes are as explained earlier in this chapter. The findings for energy compare well with the findings of other studies (see for example: Chishti and Mahmud, 1990; Christopoulos, 2000; Bjorner and Jansen, 2000; Al-Azzan and Hawdown,

1977 whose studies found energy elasticity to be around  $-0.14$ ,  $-0.19$ ,  $-0.44$ , and  $-0.347$ , respectively).

Labour demand was also price inelastic, suggesting that the manufacturing sector was less sensitive to labour price changes. With one per cent increase in the price of labour, the labour cost share in total production cost within the manufacturing sector reduces by 0.36 percent. This effect, however, was found to be insignificant.

Demand for capital was found to be almost price elastic ( $-0.88$ ). With 1 percent increase in the price of capital, its demand declines by 0.88 percent. This sector was moderately sensitive to the changes in the cost of obtaining commercial bank loans that was used as a proxy for the price of capital. The finding of this study on capital's price elasticity of demand exceeded that found by the previous studies. For example, Christopoulos (2000) and Chishti and Mahmud (1990) found price elasticities of  $-0.15$  and  $-0.24$  respectively.

Table 4.9 gives the estimated Allen-Uzawa and cross-price elasticities calculated at the mean values of the cost shares given in table 4.4. The distinction between the two types of cross elasticities as explained earlier is that, the Allen elasticity is a share-weighted cross-price elasticity that measures the proportionate change in relative factor shares induced by proportionate changes in relative price of factors. The cross-price elasticity is a more useful measure for policy purposes since it measures the proportionate change in amount of factor use induced by a proportionate change in the price of the other factor.

**Table 4.9. Allen and cross-price elasticities of the factors using the price of energy as an instrument.**

Elasticities	Estimate
Allen cross price between capital and labour	-1.25
Allen cross price between capital and energy	1.133
Allen cross price between labour and capital	1.20
Allen cross price between labour and energy	0.43
Allen cross price between energy and labour	0.7
Allen cross price between energy and capital	0.86
Cross price between capital and labour	-0.32
Cross price between labour and capital	0.09
Cross price between capital and energy	0.75
Cross price between energy and capital	0.07
Cross price between labour and energy	0.29
Cross price between energy and labour	0.18

Source: Own calculations

From the results in table 4.9, energy and capital, energy and labour were found to be substitutes. Labour and capital, and energy and technology were found to be complementary inputs in the production processes within the manufacturing sector. The substitution relationships between energy and technology, labour and energy, and energy and capital were found to be significant. The positive cross-price elasticity as expected given that the period covered was long (36 years) which allowed the manufacturing firms to substitute capital with other factors of production. However, the substitution possibilities between the factors were very limited as shown by the cross price elasticities. For example, the cross price elasticity

between energy and capital was 0.07. Chishti and Mahmud (1990) found capital and energy to be complements which was in contrast to the findings of this study. In spite of this, the Chishti and Mahmud's study suggested low substitution possibilities between the two factors. With these limited substitution possibilities between factors of production, the costs of production may rise significantly as a result of increases of the prices of the inputs especially energy price shocks which were common in Kenya. The Kenyan manufacturing firms seem to be faced with difficulties in obtaining the best-input combinations that minimize total cost.

The Allen–Uzawa elasticities gave a different picture that suggested the substitution possibilities are higher. For example Allen cross price elasticity between labour and capital (1.20), but the cross price elasticity was 0.09 suggesting that the changes in the price of capital will not induce substantial changes in the use of labour.

The conclusion of this part of the estimation is that the price of energy, technology, value added, the price of capital, and the unusual events significantly influence use of energy in the Kenyan manufacturing sector. Also, the study found that energy, labour and capital were substitutes in the total production in this sector.

## **4.11. Co-integration Analysis**

### **4.11.1. Introduction**

The results of unit root tests suggested that most of the series used in this study were non-stationary in levels. With non-stationarity of the variables at levels, appropriate models for energy use were to be estimated with variables in their first differences. The obvious problem

of such a solution that is the loss of information on any long-run relationship between variables can be solved by co-integration analysis (Engle and Granger, 1987). This technique shows that even if in the short-run variables drift apart, in the long-run, they may be moving together. Individual series may be  $I(1)$  but a linear combination of the series may be  $I(0)$ . This linear combination was taken to represent a long-run equilibrium relationship between variables contained in the energy utilization model (energy share equation). Figures E5 to E8 (see appendix E) show the residuals of electricity, oil, total energy and labour estimated models. Graphical observation showed that the estimated residuals of all estimated models were stationary.

To properly investigate this long-run equilibrium, Engle-Granger two-stage procedure was used. Thus, unit root tests were performed on the residuals from the total energy, and for the various types of energy that is electricity and oil and on the residual of the demand for other factors of production. Following the standard practice, the study used the augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981). If the ADF test indicated the presence of a unit root, then the residuals of demand functions were non-stationary implying that the estimated relationships were not structural.

This test was done to find out whether long run relationship exists between the dependent variables (oil and electric fuel) and their determinants, and also on total energy and, labour and their hypothesized determinants. Unit root tests were carried out on the residuals of the equation whose results are presented in tables 4.3 and 4.7.

Table 4.10 show the unit root test results for the co-integration regressions.

**Table 4.10: Unit root test for the co integration relationship**

Estimated residual	equation	Coefficient	ADF statistic
Electricity		-0.62**	-3.26
Oil		-0.62**	-3.26
Total energy		-0.80*	-3.8
Labour		-0.60***	-2.8

Source: Own calculations

\*, \*\*, \*\*\* Denotes significant at 1%, 5% and 10% respectively

Note: The critical value of both the ADF statistic (with no constant and no time trend) is -1.95 at 5% level. The ADF tests were performed without constant term because it is known that the residuals have zero mean.

The results shown in table 4.10 are statistically significant. As shown by the ADF test, all residuals were stationary at levels, that is  $I(0)$ . There was thus strong evidence of the existence of a co-integrating relation in all share equations. There was evidence that there was a long-run relationship between the fuels utilized in the sector and own prices, cross prices, value added, technology, prices of capital and labour, and unexpected events in the energy sector. This implied that even if the level of energy utilized by manufacturing firms, prices of energy, prices of labour and capital, output and technology drift apart in the short-run, in the long run, they moved together. With this then, the levels estimation of the energy function was not spurious.

Co-integration analysis therefore, showed that there was a long-run relationship between factor demands utilization and their determinants. The following section presents the results of error correction model.

#### **4.12 Results of the Error Correction Model**

Although the results in section 4.11 indicated that in the long-run the cost shares and, price of energy, price of labour, price of capital, value added and technology tend to converge towards a long run equilibrium path, in the short-run, they may diverge from the equilibrium path.

The disequilibrium between short- and long-run values in lagged year would be corrected quickly or slowly in the current year by changes in the levels of factor demands and their determinants, through various policies such as energy policy and macroeconomic policies.

To investigate this adjustment, the ECM in equation 3.14 of this study, was estimated and the results are presented in table 4.11.

**Table 4.11: Summary of the Error Correction Model for all the factor shares in total manufacturing cost**

Variable	Value of the coefficient in a share equation i				
	Total energy	Labour	Capital	Electricity	Oil
Constant	0.006(0.073)	-0.015(-0.45)	0.007(0.101)	0.014(0.7)	-0.014(-0.74)
Change in log of price of energy )	0.001(0.04)	-0.03(-1.6)	0.02(0.64)		
Change in log of price of labour	0.006(0.033)	0.09(1.16)	-0.20(-1.4)	-0.04(-1.0)	0.04(0.99)
Change in log of output	-0.05(-0.59)	0.009(0.27)	0.005(0.08)	0.023(1.18)	-0.02(-1.18)
Change in price of capital	-0.002(-1.13)	-0.004(-5.8*)	0.004(3.4*)	-0.006(-1.94)	0.007(1.94)
Change in technology	-0.006(-0.08)	0.03(0.9)	-0.008(-0.12)	0.002(0.10)	-0.002(-0.101)
Change in the log of price of electricity				0.22(0.8)	-0.23(-10.82)
Change in the log of price of oil				-0.15(-9.6)	0.16(9.6)
Dummy	-0.19(-3.4*)	-0.39 (-12*)	0.28(3.9*)	-0.03(-2.8*)	0.031(2.78*)
Residual (-1)	-0.36(-1.3)	-0.05(-0.6)	-0.7(-1.4)	-0.4(-2.4*)	-0.4(-2.4*)
R-squared	0.43	0.81		0.93	0.93
Adjusted R-squared	0.28	0.85		0.91	0.91
Durbin-Watson stat	2.1	1.56		2.0	2.0

Source: Own calculations

Figures in parentheses are the t values. \* Indicates significant at 5 percent. Note: D=1 for total energy function for the years 1993,2002, =0, otherwise. D=1 for labour function for the year 2003, =0, otherwise. D=1 for electricity and oil functions for the years 1980, 2000, 2003 =0, otherwise.

Apart from the energy error correction model whose explanatory power was found to be low (0.28), the rest of the estimated error correction models fit the data well as shown by the high values of the adjusted R squared, which range from 0.85 to 0.91.

The study found unexpected events in the energy market to significantly influence short-run energy use within the sector of study. These unusual events include the effects of 1992 and 2002 multiparty elections. The price of capital and the 2003 U.S led military attack of Iraq significantly influenced the demand for labour within this sector in the sample period. The cost of obtaining loans for investment and the effects of multi-party elections in the economy in the year 1992 were the only significant variables affecting the use of capital in the short-run during the period of study.

In all the estimated equations, the error correction terms have the expected sign. From these coefficients, about 0.36 percent, 0.05 percent, 0.70 percent, 0.40 percent, 0.40 percent of any deviation from the long-run values of energy, labour, capital, electricity, and oil, respectively were corrected in each period. However, the error correction terms for electricity and oil were the only ones found to be statistically significant. The coefficient for capital (0.70) was the largest suggesting a stronger influence of the long- run in the capital market within the manufacturing sector.

#### **4.13 The Forecasting Power of the Estimated Demand Models**

The forecasting performance of the estimated models was investigated using two approaches. First, differences between the actual (realized) and the predicted series were obtained. The

smaller the differences between the actual values of the cost share and the predicted cost shares in total cost expenditure, the better was the forecasting performance of the factor demand model. Similarly, the smaller were the differences between the actual series and the predicted values of the particular form of energy; the better was the forecasting performance of the inter-fuel model.

The plots of the actual and estimated series of electricity, oil, total energy, and labour demands (figures A9 to A12) showed that the estimated models for the same have good forecasting power as the predicted series were observed to track the realized series well.

The second method used to evaluate the forecasting performance of the estimated models was the computation of Theil's (u) inequality coefficient for each model. It was estimated by use of equation 3.15 of this study. Table 4.12 presents the estimated values of Theil's inequality coefficient using the actual and predicted values in Appendix II, Table A6 and A7.

**Table 4.12: Theil's inequality coefficients for the estimated models**

Equation	Theil's inequality coefficient
Electricity	0.38
Total energy	0.64
Labour	1.07

Source: Own calculations

The study found the coefficient for the electricity share equation to be 0.38, which was less than unity. Therefore, the forecasting performance of the electricity demand function was fairly good. The Theil's inequality coefficient for the total energy demand function was found

to be 0.64, which was also less than unity. Thus, there was evidence that the forecasting performance of the total energy demand function was good. Lastly, the Theil's coefficient for the labour cost share was found to be 1.07 and therefore, sample evidence that the labour demand function estimated by this study had fair forecasting performance. The results for Theil's inequality coefficient showed that the estimated demand functions had good forecasts for their actual demand since all the coefficients, apart from the labour one were less than one and close to zero.

## CHAPTER FIVE

### SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Summary

This study examined the demand for different types of energy, namely oil and electricity and the elasticity of substitution among energy components. The study also investigated the determinants of total energy used in the manufacturing sector and the substitution possibilities among total energy and aggregate non-energy factors of production within the Kenyan manufacturing sector over the 1970-2005 period. The translog model was used to generate information on how energy utilization and the non-energy factor utilization respond to changes in own prices, other input prices, value added, technology and occurrence of unusual events. Estimation was done in two stages, first the sub-energy model was estimated and an aggregate energy index was computed. In the second stage, the total factor cost shares were estimated using the estimated energy price index as an instrumental variable. Time series properties were investigated by use of the Dickey-Fuller unit root test for stationarity of the data, (ECM) and the two stages Engle –Granger (1987) procedure for co-integration.

The manufacturing sector in Kenya is the second largest user of petroleum products and the largest user of electricity. The sector uses about 25 per cent and 41 per cent of total petroleum and electricity consumed in Kenya, respectively. Utilization of electricity in this sector has been growing over the years and is expected to continue growing. One of the aims of this study was to find out substitution possibilities between electricity and other fuels consumed by the Kenyan manufacturing sector. Adjustments have been done on electricity retail prices, but their effects on electric power use by the manufacturing sector are not well known. On the

other hand, use of petroleum products by this sector has been erratic over the study period. The factors responsible for this trend were part of the study.

Previous studies that have been done in Kenya (see for example; Senga *et al.*, 1980; Kimuyu 1988), analyzed economy-wide demand for energy, but none of them has singled out the manufacturing sector, which is a major user of commercial energy. Other studies (see for example, Gor 1994; Sasia 1987) have investigated energy demand by residential sector and energy product demand, respectively. Almost all the studies have used time series data where stationarity of the data was assumed. None investigated the time series properties of the data. Results obtained from most of these studies were therefore questionable given that proper account of time series properties of the variables used in their respective investigations was not done. In contrast to previous studies, this study incorporates increasingly popular econometric diagnostic techniques, stationarity tests (Engle and Granger 1987), and co-integration model and ECM to account for short-run and long-run phenomenon of the data.

In the thirty- six years span from 1970 through 2005, the energy sector experienced several events including the droughts of 1980s and 1999-2001, the oil crises of 1973, and 1979, the oil glut of 1986, and energy reforms which were gradually introduced between 1994 and 2000. At the same time, wage employment in the manufacturing sector increased by 179 per cent while nominal value added increased by 79 per cent in the period 1970-2005. The effects of these events on energy use in a larger energy-consuming sector such as the Kenyan manufacturing are not fully known. This study fills this knowledge gap by analyzing the effects of these variables on energy use by the manufacturing sector.

## 5.2 Conclusions

Overall, electricity takes a larger market share in the total energy utilized by the manufacturing sector. The average price of petroleum products was found to be more unstable over the study period than the price of electric fuel. Oil prices are determined by the events in the international oil market, which keep on fluctuating depending on the conditions of supply and demand.

Supply, distribution and generation of energy in Kenya are dominated by a few firms. Most of the electricity is generated locally, however 30MW are imported from Uganda. The country imports all its fossil energy. There were no recorded data that show that the sector utilizes biofuels.

Inter-fuel estimation results provided evidence that oil and electricity were significant substitutes in the Kenyan manufacturing sector. However, the substitution possibilities were low. There was little evidence that electricity and oil substitute each other in order to minimize the cost of energy in the Kenyan manufacturing sector. The study found electricity and oil to be price inelastic. Apart from own price, other factors that determined the use of electricity and oil included, value added, technological progress and unexpected events. The droughts of 1980, 2000 and the 2003 US led military invasion of Iraq significantly affected energy use within this sector.

As regards the substitution between energy and non-energy factors, the study found that all factors were substitutes in the Kenyan manufacturing sector. However, the substitution coefficients were low but, statistically significant. Therefore, there was some evidence that energy, labour, and capital substitute for each other in the production process in the Kenyan

manufacturing sector. Given that energy price shocks are common in the developing world, this result suggests that price increases on energy may lead to substantial increase in the cost of production of the manufacturing firms. Demand for energy and labour was found to be price inelastic. The price elasticity of capital was approximately unity. Total energy demand was found to be mainly determined by own price, price of capital, and technology. Across models unexpected events determined the demand for each. Multi-party elections of the year 2002 and the drought of 1980 affected significantly the use of the three factors (energy, capital and labour) considered in this study.

Co-integration analysis revealed that there was a long-run relationship between all the factor demands within the manufacturing sector and their determinants. There was evidence that there was long-run relationship between electricity, oil and their own prices, prices of non-energy factors, value added, unusual events, and technology.

The error correction terms in each function had the expected (negative) sign and they all were statistically significant. From their coefficients, about 0.36 percent, 0.05 percent, 0.70 percent, 0.40 percent, 0.40 percent of any deviation from the long-run values of energy, labour, capital, electricity, and oil, respectively were corrected in each period.

### **5.3 Policy Implications**

The results of the study have important policy implications. First, there exists a stable long-run relationship among the variables over the study period. Second, that own price, cross price, and price of capital, technology, and unexpected events in the economy are important in influencing energy utilization. These are important to energy policy-makers and planners, as they will assist them in coming up with effective policies and plans on energy demand. Also,

given that energy was found to be price inelastic, it means that energy price policy alone cannot be effective in controlling future energy demand among the Kenyan manufacturers. Other policies need to be implemented at the same time as price policy change such as energy conservation measures and awareness programmes to control energy demand. The study revealed that electricity and oil were substitutes, but the substitution possibility was low. Whenever energy prices rise, the Kenyan manufacturers are unable to adjust substantially their demand of different forms of energy in order to minimize the cost of energy. With little substitution possibilities among energy and non-energy factors (labour and capital), any energy price shocks will increase substantially the cost of production of the manufacturing firms. The government, therefore, needs to enhance its effort in oil exploration to have its own domestic source so as to reduce dependence on foreign supply of oil. Lastly, improvement in technology is very important especially in the energy sector, as it leads to conservation of energy especially in the oil sector. Technology progress was found to significantly reduce demand for energy. More research needs to be done on technology especially on the energy appliances, which are energy -saving.

#### **5.4 Recommendations**

The government should put more effort on development of other forms of energy such as biofuels so as to avail more forms of energy to the manufacturing sector and help to lower the price volatility of energy. These include biodiesel, ethanol and biogas among others. The biofuels are carbon dioxide neutral hence are friendlier to the environment compared to fossil energy. A biofuel such as biodiesel can be used by the manufacturing sector on their transportation needs since it can be used with existing vehicles with little or no changes in the vehicle engines. Biofuel industries are expanding very fast in other countries including Europe, Canada, India, Asia and the United States of America. However, the country should take care not to create other problems such as deforestation and food shortages which result

from development of biofuels. These can be prevented by growing crops which can be used to generate biofuels such as sugarcane. This will raise the energy price elasticities obtained in this study and also work on the balance of payments positively by reducing the country's expenditure on energy imports.

The study recommends another study on the same sector but using firm level data so as to compare the results. The study also recommends that data on electricity consumption be categorized according to economic sector, not by the type of the consumer, so that actual quantity of electricity utilized by each sector can be obtained. There is also need for another study in the same sector but using different methodology for comparison purposes.

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## APPENDICES

### APPENDIX I: Data Collection Schedule

**Table A1: Guidelines for collecting data**

Year	Variable							
	Employees	Value added	Oil	Electricity	Price of oil	Price of electricity	Interest rate	Price of labour
1970								
1971								
1972								
1973								
1974								
1975								
1976								
1977								
1978								
1979								
1980								
1981								
1982								
1983								
1984								
1985								
1986								
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1993								
1994								
1995								
1996								
1997								
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								

Source: Own construction

**APPENDIX II: Data**

**Table A2: Nominal data for the variables**

Year	Employment (numbers)	Electricity sales to Industrial (GWh)	CPI 1995=100	Nominal Electricity price (Kshs/KWh)	Value added to the Manufacturing sector (KShs.)	GDP Deflator 1995=100	Petroleum sales to Industrial sector (tonnes)
1970	82256	273	3.52706	0.241	1243200000	20.2769	348000
1971	92803	323	3.66039	0.284	1433600000	21.1982	347900
1972	95273	375	3.87386	0.298	1687000000	13.1746	351000
1973	94453	414	4.2334	0.319	1978000000	14.1353	349870
1974	101332	485	4.98736	0.319	2381400000	16.562	359000
1975	100731	563	5.94095	0.319	2680200000	18.0319	349870
1976	108776	639	6.62114	0.32	2883600000	20.3718	297640
1977	117949	743	7.60245	0.287	3598800000	16.4769	370200
1978	130056	814	8.88968	0.335	4386400000	24.1772	340988
1979	138409	888	9.59902	0.354	4996800000	17.6031	418100
1980	141280	966	10.9293	0.37	5902800000	19.1169	497300
1981	146338	1026	12.1974	0.39	6848800000	20.8595	457500
1982	146780	1051	14.7182	0.407	7688800000	23.1066	465420
1983	148758	1074	16.3958	0.59	8165200000	25.2001	469600
1984	153145	1136	18.0819	0.6	9218000000	27.353	479750
1985	159351	1269	20.4337	0.63	10368000000	30.8092	498700
1986	163903	1402	20.9516	0.63	12164600000	33.5008	455800
1987	165921	1514	22.7613	0.68	13049400000	35.3106	483400
1988	174093	1531	25.553	0.9	15059200000	38.3242	489800
1989	178695	1617	29.0766	0.9	17107200000	41.5451	459800
1990	187683	1721	34.2469	1.19	19748000000	45.4395	454400
1991	188873	1738	41.1252	1.43	23348000000	51.3676	453500
1992	190296	1823	52.3657	1.573	24614600000	61.0753	467900
1993	192087	1857	76.4429	1.87	28393600000	76.7704	442800
1994	203528	1904	98.4695	2.35	33930400000	89.8428	408900
1995	210775	2014	100	3.67	38911000000	100	425800
1996	216411	2150	108.864	3.7	45644600000	109.025	403100
1997	220484	2193	121.233	3.8	54606900000	124.769	374400
1998	216889	2205	129.383	3.9	65970700000	138.615	367200
1999	219604	2238	136.812	3.45	78534700000	153.983	413800
2000	217896	2221	150.466	3.32	87973600000	155.946	382500
2001	216600	2194	159.101	2.9	96968500000	175.787	310000
2002	229800	2255	162.221	4.47	1.10853E+11	176.7	310000
2003	239700	2369	162.344	4	1.23900E+11	178.45	382500
2004	242000	2587	164.432	3.8	1.24812E+11	179.43	310000
2005	246700	2739	166.103	5	1.34272E+11	180.23	280000

Source: Republic of Kenya *Economic Survey*, Various Issues. *Statistical Abstract*. Various issues. Nairobi: Government Printer.KPLC Records, and International Financial Statistics CD-ROMS

**Table A3: Refined data**

Year	Energy (TOE) (000)			Real value added (kshs)
	Electricity	Oil	Total	
1970	23.47	34.78	58.25	6131114717
1971	27.77	34.77	62.54	6762838354
1972	32.24	35.08	67.32	12804942845
1973	35.60	34.96	70.56	13993335833
1974	41.70	35.86	77.58	14378698225
1975	48.41	34.96	83.37	14863658294
1976	54.94	29.74	84.69	14154861132
1977	63.89	36.93	100.81	21841487173
1978	69.99	37.00	106.97	18142712969
1979	76.35	34.08	110.43	28385909300
1980	83.06	41.78	124.84	30877391209
1981	88.20	49.70	137.92	32833001750
1982	90.37	45.72	136.09	33275341244
1983	92.35	46.52	138.86	32401458724
1984	97.68	46.93	144.61	33700142580
1985	109.11	47.94	157.06	33652285681
1986	120.55	49.84	170.39	36311371669
1987	130.18	45.55	175.73	36956041529
1988	131.64	48.31	179.95	39294231843
1989	139.03	48.95	187.98	41177419238
1990	147.98	45.95	193.93	43459985255
1991	149.44	45.41	194.85	45452775680
1992	156.75	45.32	202.07	40302053367
1993	159.67	46.76	206.43	36985088003
1994	163.71	44.25	207.96	37766409774
1995	173.17	40.86	214.04	38911000000
1996	184.87	42.55	227.42	41866177482
1997	188.56	40.28	228.85	43766400308
1998	189.60	37.41	227.01	47592756917
1999	192.43	36.69	229.13	51002188553
2000	190.97	41.35	232.32	56412860862
2001	188.65	38.22	226.87	55162497796
2002	193.90	30.98	224.87	55567435442
2003	294.46	27.98	322.44	55400000000
2004	222.44	29.08	251.52	44500000000
2005	235.52	36.27	271.79	50200000000

Source: Own Calculation

**Table A4: Wholesale prices of petroleum products (KShs. per tonne)**

	LPG	Premium	Regular	Illuminating Kerosene	Light Diesel	Industrial Diesel	Fuel oil
1970	1960	1398	1398	675	357	397	332
1971	1940	1459	1398	675	357	397	332
1972	2010	1459	1468	736	392	471	334
1973	2060	1551	1468	736	392	471	334
1974	2060	1551	1468	736	392	471	334
1975	2060	1551	1468	736	392	471	334
1976	2980	3198	3311	1584	1876	1295	796
1977	3100	3569	3515	1689	2029	1395	875
1978	3120	3729	3679	1711	2219	1415	891
1979	3374	4180	4329	1944	2433	1585	1045
1980	4044	6022	5475	2539	3207	1648	1103
1981	4611	8034	7654	2994	4690	2245	2518
1982	6050	10116	9738	4333	5886	3077	1802
1983	6399	10116	9738	4333	5886	3666	2195
1984	6146	10869	10512	4859	6365	4019	2408
1985	5893	10445	10146	4859	5656	4019	2408
1986	5894	10021	9779	4052	5656	3136	2515
1987	6147	10926	9779	4012	6005	3136	2515
1988	6400	11831	11337	5033	7227	3982	2408
1989	7820	13441	13551	7762	10019	4668	3164
1990	12679	16539	16330	7762	10019	7562	4457
1991	14661	16539	16330	11211	14599	7562	4457
1992	16643	23327	23201	17408	21921	12033	8851
1993	22655	32028	32190	16534	24004	18720	14520
1994	24454	35386	35488	17247	23813	21915	15476
1995	25200	37906	37632	19634	31788	18896	13970
1996	25956	45712	46661	19634	31788	24326	18364
1997	45000	49002	48672	25031	33456	23798	18372
1998	42000	51049	51196	24504	34267	23912	17675
1999	51000	63200	64600	34069	44700	35090	25900
2000	55110	47980	47116	38886	32498	38610	25520
2001	52410	45382	44504	37156	29176	32610	22800
2002	53320	48178	47289	37958	30953	33708	16059
2003	54230	49267	48368	36878	30920	35299	18229
2004	55140	57730	56730	49730	39430	36890	20390
2005	56342	58450	57120	50643	40520	37930	21367

Source: Republic of Kenya, (1980, 1990, 2006)

**Table A5: Prices of energy and non-energy inputs**

	Real price of:			
	Electricity (Kshs/K Wh)	Capital (%)	Labour (Kshs/employee.)	Oil (Kshs/tonne)
1970	6.8329	0.6	14141	17893.04
1971	7.7587	1.3	17622	24635.34
1972	7.6926	-1.2	17893	24590.78
1973	7.5353	2.4	18456	26780.45
1974	6.3962	2.3	18874	20085.06
1975	5.3695	1.6	18312	21974.56
1976	4.8330	-2.2	18866	32450.17
1977	3.7840	1.4	18120	25789.45
1978	3.7690	-2.6	17274	26939.75
1979	3.6900	1.6	16442	28112.99
1980	3.3854	-1.8	17316	23798.53
1981	3.1974	1.4	16816	20941.5
1982	2.7653	-6.3	14910	39797.18
1983	3.5985	0.5	14466	36884.88
1984	3.3182	4.9	14612	35693.15
1985	3.0831	3.3	14276	30360.21
1986	3.0069	8.34	14197	25987.37
1987	3.0000	6.9	14012	26686.90
1988	3.5221	2.7	14204	26956.86
1989	3.0953	2.2	17516	29687.59
1990	3.4748	3.2	20567	34658.62
1991	3.4690	9.4	23563	29651.27
1992	3.0039	2.5	24788	33659.98
1993	2.4463	26	24812	30022.60
1994	2.3865	2.1	26860	31850.43
1995	3.6700	2.1	28954	26432.29
1996	3.3987	31.5	30895	27877.64
1997	3.1345	19.2	31257	28673.36
1998	3.0143	20.5	30897	29671.65
1999	2.5217	19.4	33468	33263.48
2000	2.2065	9.6	33688	27127.15
2001	1.8227	16.3	35784	34130.20
2002	2.8788	3.7	36848	23553.85
2003	2.867	3.7	37569	29845
2004	2.457	0.7	35467	34647
2005	2.341	2.9	38746	33764

Source: Kenya Power and Lighting Company, various issues; Republic of Kenya, *Economic Surveys* various issues and Republic of Kenya, *Statistical abstract* various issues. Nairobi: Government printer

**Table A6: Energy market shares 1970-2005**

Year	Energy share markets (%)		Total
	Electricity	Oil	
1970	40	60	100
1971	44	56	100
1972	48	52	100
1973	50	50	100
1974	54	46	100
1975	58	42	100
1976	65	35	100
1977	63	37	100
1978	65	35	100
1979	69	31	100
1980	67	33	100
1981	64	36	100
1982	66	34	100
1983	67	33	100
1984	68	32	100
1985	69	31	100
1986	71	29	100
1987	74	26	100
1988	73	27	100
1989	74	26	100
1990	76	24	100
1991	77	23	100
1992	78	22	100
1993	77	23	100
1994	79	21	100
1995	81	19	100
1996	81	19	100
1997	82	18	100
1998	83	17	100
1999	84	16	100
2000	82	18	100
2001	83	17	100
2002	86	14	100
2003	91	9	100
2004	88	12	100
2005	87	13	100

Source: Own calculation

**Table A7: Input cost shares**

Year	Fuel cost shares		Total input cost shares		
	Electricity	Oil	Energy	Labour	Capital
1970	0.226247	0.769483	0.920363	0.043505	0.028002
1971	0.226247	0.773753	0.930291	0.043505	0.026204
1972	0.250495	0.749505	0.923112	0.044889	0.031999
1973	0.249784	0.750216	0.920341	0.050404	0.029255
1974	0.300809	0.699191	0.89409	0.069705	0.036205
1975	0.282229	0.717771	0.892988	0.077533	0.029479
1976	0.24228	0.75772	0.891684	0.079048	0.029269
1977	0.227824	0.772176	0.839441	0.084619	0.07594
1978	0.235254	0.764746	0.826406	0.091379	0.082216
1979	0.254742	0.745258	0.816542	0.104108	0.07935
1980	0.247366	0.752634	0.814325	0.119952	0.065723
1981	0.239547	0.760453	0.759589	0.121348	0.119063
1982	0.137652	0.862348	0.85049	0.096298	0.053212
1983	0.183759	0.816241	0.831014	0.105095	0.063891
1984	0.183601	0.816399	0.799886	0.146676	0.053437
1985	0.211741	0.788259	0.773421	0.172014	0.054564
1986	0.245448	0.754552	0.730448	0.198215	0.071337
1987	0.27188	0.72812	0.709546	0.214309	0.076145
1988	0.292691	0.707309	0.683922	0.232529	0.083548
1989	0.256065	0.743935	0.695761	0.254013	0.050226
1990	0.272862	0.727138	0.691803	0.237824	0.070373
1991	0.309144	0.690856	0.653271	0.282175	0.064554
1992	0.264023	0.735977	0.637532	0.298773	0.063695
1993	0.24436	0.75564	0.338691	0.212539	0.44877
1994	0.243678	0.756322	0.500173	0.41055	0.089277
1995	0.40613	0.59387	0.437873	0.461053	0.101074
1996	0.381033	0.618967	0.486082	0.411524	0.102394
1997	0.372929	0.627071	0.432132	0.47311	0.094758
1998	0.374335	0.625665	0.386067	0.533756	0.080177
1999	0.316027	0.683973	0.354162	0.576799	0.06904
2000	0.303897	0.696103	0.313446	0.618036	0.068517
2001	0.234497	0.765503	0.291631	0.648453	0.059915
2002	0.470637	0.529363	0.233926	0.705157	0.060918
2003	0.408001617	0.591998383	0.54734724	0.323634413	0.129028347
2004	0.37001198	0.62998802	0.544664792	0.327469474	0.127865734
2005	0.343178197	0.656821803	0.539560422	0.319188543	0.141251035

Source: Own calculations

**APPENDICIII: Estimated correlation and predicted values**

**Table A8: Correlation coefficients among the variables**

	Y	Y/E	P <sub>k</sub>	T	P <sub>o</sub>	P <sub>EL</sub>	P <sub>E</sub>	P <sub>L</sub>	O	EL	E	Y/EL	Y/O
Y	1												
Y/E	0.6	1											
P <sub>k</sub>	0.5	0.02	1										
T	0.9	0.3	0.5	1									
P <sub>o</sub>	0.5	0.3	0.1	0.5	1								
P <sub>EL</sub>	-0.8	-0.6	-0.3	-0.8	-0.5	1							
P <sub>E</sub>	0.17	0.4	-0.1	0.1	0.6	-0.4	1						
P <sub>L</sub>	0.7	0.1	0.5	0.9	0.3	-0.4	-0.2	1					
O	0.2	0.4	0.1	0.01	0.1	-0.4	0.4	-0.4	1				
EL	0.9	0.3	0.6	0.9	0.4	-0.8	0.1	0.8	0.1	1			
E	0.9	0.3	0.5	0.9	0.5	-0.8	0.1	0.7	0.1	0.9	1		
Y/EL	-0.3	0.5	-0.4	-0.5	-0.1	0.3	0.1	-0.5	0.1	-0.6	-0.5	1	
Y/O	0.9	0.5	0.4	0.9	0.4	-0.7	0.1	0.9	-0.2	0.9	0.9	-0.3	1

Source: Own calculations

Where, Y= output, Y/E= energy efficiency, T= technology, P<sub>o</sub>= price of oil, P<sub>EL</sub>= price of electricity, P<sub>L</sub>= price of labour, O= oil, EL= electricity, E= energy, Y/EL electricity efficiency, Y/O oil efficiency.

**Table A9: Predicted cost shares of electricity, total energy and labour**

Year	Electricity	Total energy	Labour
1970	0.247847	0.946716023635	0.0001945896103
1971	0.233122	0.932195394307	0.0199694436762
1972	0.284122	0.883706156771	0.0877896822993
1973	0.274496	0.862709593472	0.0952998945121
1974	0.310480	0.833806755546	0.1242417057910
1975	0.270001	0.868641976852	0.0844892573229
1976	0.185246	0.964990391811	0.0084809357033
1977	0.215174	0.854679183738	0.0974557581547
1978	0.202293	0.899947012006	0.0551410696949
1979	0.219503	0.826159019196	0.1191546749860
1980	0.254811	0.811878664272	0.1469973843480
1981	0.241338	0.767731626352	0.1780826143800
1982	0.134906	0.867892178701	0.0904307616417
1983	0.192907	0.838265020077	0.0907533355256
1984	0.190042	0.77779575151	0.1362301137150
1985	0.215208	0.748441619512	0.1690409647160
1986	0.246904	0.678120090247	0.2225823548420
1987	0.250124	0.680896428042	0.220784300347
1988	0.292779	0.71066507245	0.202159340503
1989	0.272608	0.690802268701	0.231107741723
1990	0.281245	0.697466699129	0.223689837097
1991	0.328230	0.598607291171	0.305177121029
1992	0.286868	0.651390905267	0.270966230235
1993	0.248809	0.429513288507	0.415530796319
1994	0.270372	0.590416239222	0.332817927541
1995	0.395886	0.406959158276	0.515729093837
1996	0.356191	0.377997091043	0.449246195541
1997	0.359495	0.450972621754	0.414602618731
1998	0.356240	0.424970458656	0.434433917666
1999	0.319074	0.397665908582	0.468527338085
2000	0.324686	0.407838216736	0.492753537332
2001	0.281639	0.30916997705	0.571935984099
2002	0.456631	0.264839075724	0.650480773163
2003	0.385422	0.474609413622	0.435567353128
2004	0.363770	0.495153287344	0.415230536037
2005	0.336206	0.468408241719	0.437204555073

Source: Own calculations

## APPENDIX IV: International Energy conversion factors

### Table A10: Energy Conversion Factors

One tonne= 0.0999331 TOE

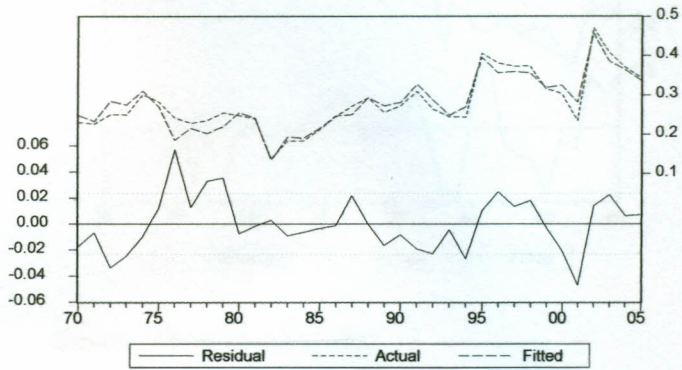
One KWh= 0.000086 TOE

One GWh= 85.9845228 TOE

Source: <http://www.onlineconversion.com/energy.html>.

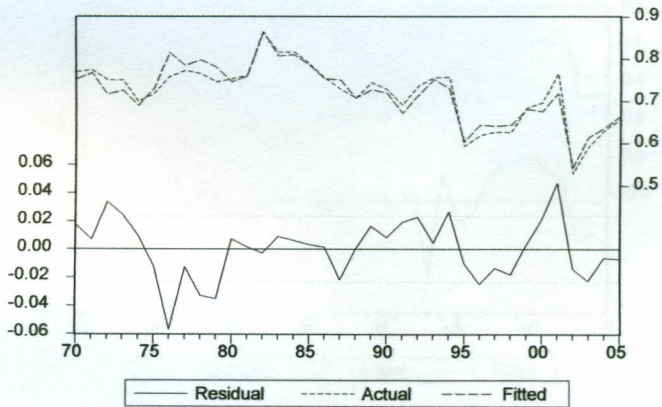
## APPENDIX V: Graphs of Residuals, Actual and Predicted Values of Inputs

**Figure A1: Plot of the residual, actual and fitted values of electricity share equation**



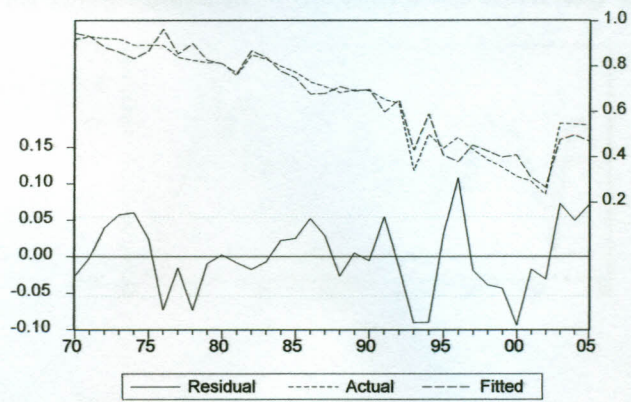
Source: Own construction

**Figure A2: Plot of the residual, actual and fitted values of oil share equation**



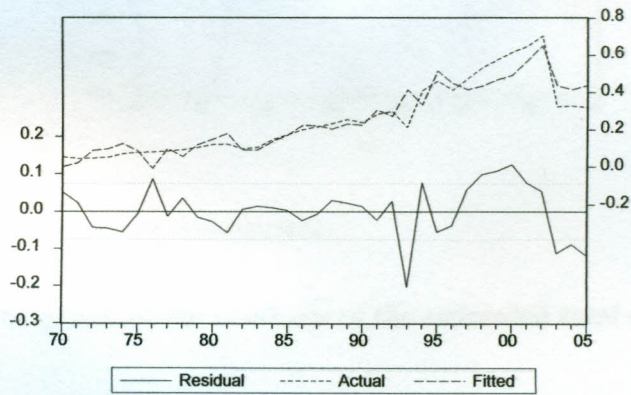
Source: Own construction

**Figure A3: Plot of the actual and estimated series and the regressed residuals of energy cost share equation**



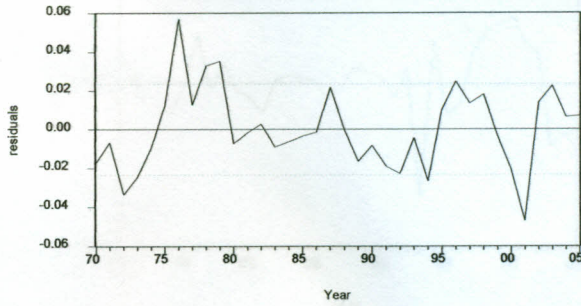
Source: Own construction

**Figure A4: Plot of the actual and estimated series and the regressed residuals of labour cost share equation**



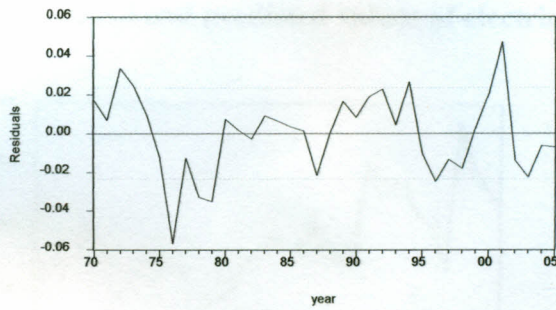
Source: Own construction

**Figure A5: The graph of the residuals of the estimated electricity model**



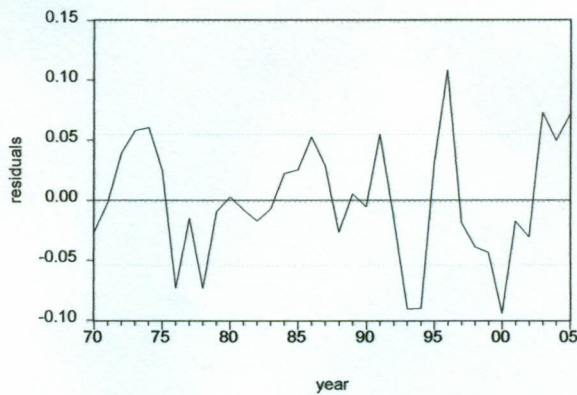
Source: Own construction

**Figure A6: The graph of the residuals of the estimated oil model**



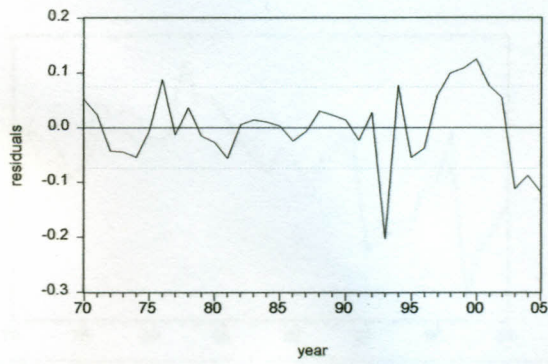
Source: Own construction

**FigureA7: The graph of the residuals of the estimated total energy model**



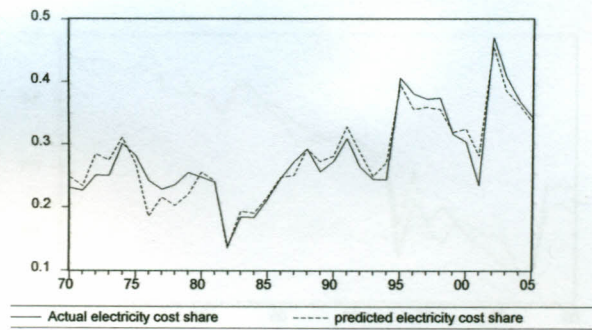
Source: Own construction

**FigureA8: The graph of the residuals of the estimated labour model**



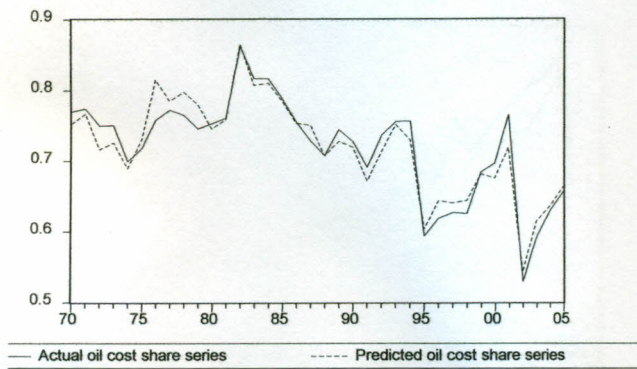
Source: Own construction

**Figure A9 : Trends of actual and predicted values of electricity demand, 1970-2005**



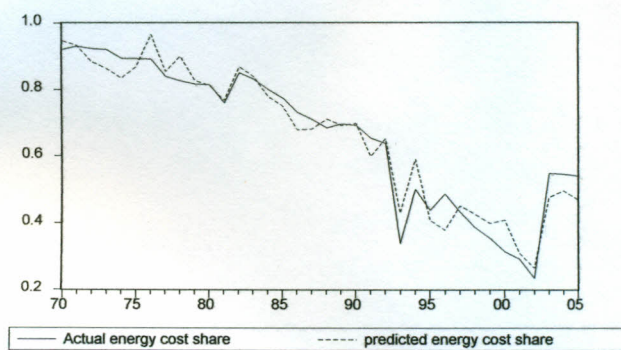
Source: Own construction

**Figure A 10 : Trends of actual and predicted values of oil demand , 1970-2005**



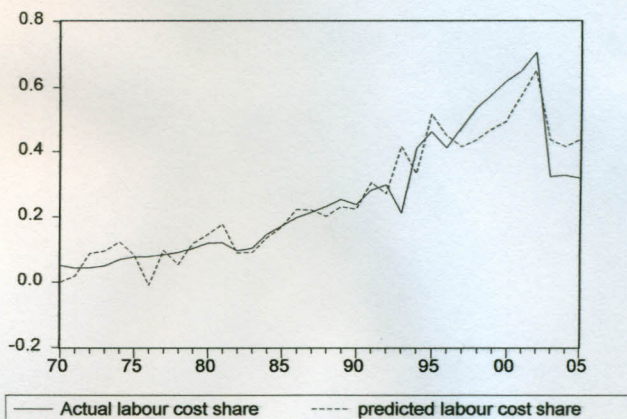
Source: Own construction

**Figure A 11 : Trends of actual and predicted values of total energy demand, 1970-2005**



Source: Own construction

**Figure A12 : Trends of actual and predicted values of labour demand , 1970-2005**



Source: Own construction

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