Discussion Paper Series

The Relationship Between Electricity Consumption and Output in Kenya's Manufacturing Sector

Mary Karumba

DP/129/2012

THE KENYA INSTITUTE FOR PUBLIC POLICY RESEARCH AND ANALYSIS (KIPPRA)

YOUNG PROFESSIONALS (YPs) TRAINING PROGRAMME

The Relationship between Electricity Consumption and Output in Kenya's Manufacturing Sector

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Kenya Institute for Public Policy
Research and Analysis

KIPPRA Discussion Paper No. 129
2012

The KENYA INSTITUTE for PUBLIC POLICY RESEARCH and ANALYSIS

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Published 2012

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ISBN 9966 777 91 1

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KIPPRA acknowledges generous support from the Government of Kenya (GoK), the African Capacity Building Foundation (ACBF), and the Think Tank Initiative of IDRC.

Abstract

This study investigates the relationship between electricity consumption and output produced by the manufacturing sector in Kenya, while accounting for fixed investment, employment (labour), and prices of oil and electricity. Data for the period 1970-2008 was utilized, a multivariate analysis was carried out based on a VECM, because although the series were unit root processes, they were found to be integrated of first order, hence co-integration, and some of the variables of the study were endogenous.

The study shows unidirectional causal relationship running from output of the manufacturing sector to electricity consumption, leading to the conclusion that information about the extent of the manufacturing sector is important in predicting the amount of electric power used by the sector. Additionally, the results imply that the manufacturing sector in Kenya is not electricity-dependent, and a shock in power consumption will not lead to a significant change in the output. The results of the study are consistent with Wolde-Rufael (2009) who found that a unidirectional relationship running from economic growth to electricity consumption exists in Cameroon, Ghana, Nigeria, Senegal, Zimbabwe and Zambia. The results, however, contradict those of Soytas and Sari (2007), who found a unidirectional relationship running from energy consumption to economic growth in the Turkish manufacturing industry. The results of this study are unique in that limited analysis has been carried out in such disaggregated levels.

This study recommends implementation of energy audits (efficiency measures) by the Energy Regulatory Commission in the manufacturing sector to conserve energy use, as well as inclusion of the output of the manufacturing sector in the forecast model of the Least Cost Power Development Plans. The manufacturing sector should also prepare indicative plans to show planned production, and the same used by energy planners to inform electric power generation and transmission investment plans.

Abbreviations and Acronyms

ADF	Augmented Dickey Fuller
ARDL	Autoregressive distributed lag
IEA	International Energy Agency
ERC	Energy Regulatory Commission
GDP	Gross Domestic Product
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KPLC	Kenya Power and Lighting Company
LCPDP	Least Cost Power Development Plan
OLS	Ordinary Least Squares
PP	Phillips-Perron
VECM	Vector Error Correction Model

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1. Introduction

1.1 Energy and Economic Growth

The role of energy in economic production and growth is evident in the world economies. According to the International Energy Agency (2010), strong long-term growth in emerging economies of non-OECD countries was responsible for the overall increase in world energy demand. Even if energy is not considered in mainstream (neo classical) economic theory of production,[1] its role as an indispensable input in the economy was revealed during the 1970s oil crisis (Erbaykal, 2008). Moreover, the global financial crisis experienced during 2007-2009 led to a contraction of energy consumption by 1.2 per cent (International Energy Agency, 2010), implying a relationship between energy and economic growth.

Kenya's current economic blueprint, Vision 2030, identifies energy as one of the foundations anchoring the social and economic pillars. The country is preparing for a take-off to achieve a middle income status by the year 2030. Specific sectors have been identified under the economic pillar to drive the economy towards the above goals. The sectors are: tourism, agriculture, wholesale trade, manufacturing, business process outsourcing, and financial services. Given that these sectors require energy to drive their operations, it is right to infer that Kenya's demand for energy is likely to increase in the future (Government of Kenya, 2007b).

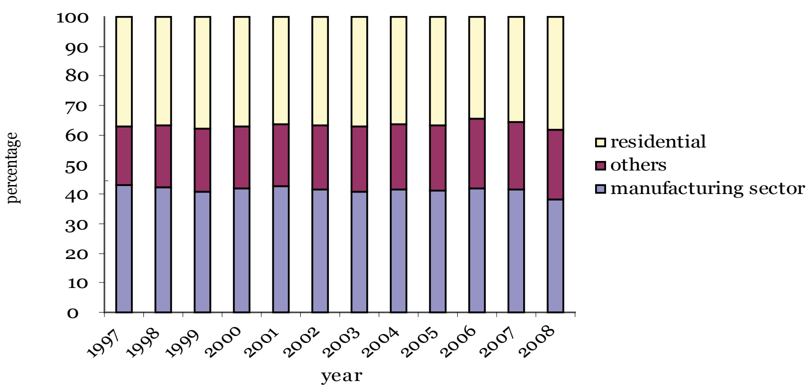
According to Government of Kenya (2007), biomass accounts for 68 per cent of the national energy requirements, while petroleum, electricity and other renewable sources account for 22, nine (9) and one (1) per cent, respectively. Notably, commercial energy in Kenya is dominated by petroleum and electricity. Electricity is the most sought after energy by Kenya society and is associated with rising quality of life. Although Kenya has experienced periods of positive economic growth, per capita consumption of electricity remains low at 121KWh, compared to 503KWh and 4,595KWh for Vietnam and South Africa, respectively (Government of Kenya, 2008). As a result, increasing electric energy consumption should be Kenya's goal as it can lead to accelerated economic growth.

[1] However, total productivity theory considers energy in the context of technological advancements that are responsible for economic growth.

Electric power in Kenya is predominantly hydro-generated, while thermal generation comes in second place and thermal proportion varies depending on the weather. According to KIPPRA (2009), one of the major challenges in the electricity sub-sector is the high cost and irregular supply of power. Inadequate rainfall reduces the amount of water needed for hydro-generation, consequently limiting power generation and the country turns to expensive and limited alternative of thermal generation. This causes power outages, which are addressed through load shedding programmes whereby a section of consumers is denied power during a specific time so as to avail to another section because demand is higher than the total supply during such periods. Thermal generated power is expensive and vulnerable to dynamics of the international oil market, and this effect is felt locally through reduced production and increased prices of goods and services due to high cost of production/operation.

From Figure 1.1, the largest single consumer of electric power in Kenya are the manufacturing and residential sectors. Notably, the manufacturing sector's share of the consumption seems to have declined during the year 2008, while the residential sector overtook the manufacturing sector. This can be attributed to the shocks that the manufacturing sector underwent during the election-related disturbances in the year 2007/2008, as well as increased rural connectivity through the intensified rural electrification programme in Kenya. Notably, residential electricity use in Kenya is mainly applied in lighting and household chores, which may not experience much shock because the activities are a necessity.

Figure 1.1: Consumption of electricity by sectors in Kenya



Source: Author's construction from Government of Kenya, Statistical Abstracts (various)

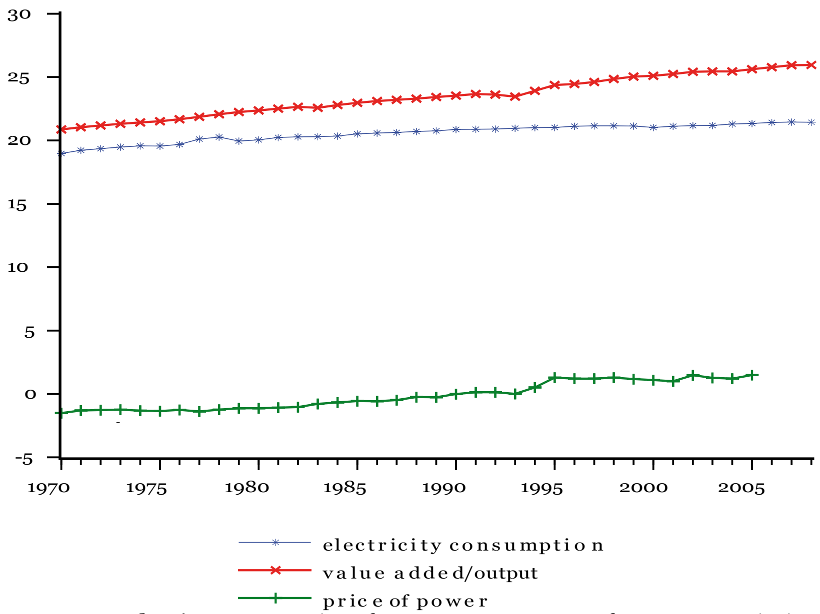
1.2 Manufacturing Sector in Kenya

Kenya's manufacturing sector comprises mainly agro-based activities, which form the core of industrial activities in the economy. These activities include production of: food and beverages, footwear and apparel, wood and paper products, pharmaceuticals and medical equipment, chemicals, petroleum, plastics and rubber, motor vehicle assembly and electricals. Further, while the industrial sector's share of GDP averages between 15 and 16 per cent, the manufacturing sector contributes about 10 per cent (Government of Kenya, 2008).

According to Government of Kenya (2007), although the sector is presented by many challenges, it is a major source of employment and as of 2008, 1.88 million people representing 14 per cent of total wage employment in Kenya were employed in the manufacturing sector (KIPPRA, 2009). Some of the challenges faced by the sector include: low value addition, low innovation and poor technological transfer, influx of contraband goods, poor infrastructure and capacity utilization, high informality and low graduation of small enterprises, weak industrial linkages, non-compliance with quality standards and unbalanced regional industrialization. With respect to energy challenges, Kenyan manufacturing firms experience power outages coupled with high prices of energy, which may lead to loss of output (KIPPRA, 2009). New developments in the manufacturing sector include introduction of energy audits to ensure compliance with energy efficiency requirements (Energy Act of Kenya, 2006). However, given the nature of manufacturing sector's activities and its linkages to the economy, the sector could be vulnerable to policy changes in the electricity sub-sector, in addition to having spillover effects to the larger economy. This effect may be particularly pronounced if firms rely heavily on electricity for production of output. Figure 1.2 presents a plot of output, piece of electricity and electricity consumption for the manufacturing sector.

Although the actual nature of the relationship between the two aspects cannot be determined from the plot, there is an apparent general upward tendency in the logarithmic values of both electricity consumption and the output of the manufacturing sector. Between 1982 and 1984, both output and electricity consumption for the manufacturing sector experienced a slight decline. However, the decline in output during the years 1992-1995 was accompanied by a less than decline in electricity consumption, while the increase in

Figure 1.2: Electricity consumption, price of electricity and output in the manufacturing sector



Source: Author's construction from Government of Kenya Statistical Abstract and Economic Surveys (various)

electricity consumption in 1976-1977 was not accompanied by any shock in the output. Notably, electricity consumption has experienced very little growth in the entire period of plot compared to the output of the manufacturing sector. When price of electricity is incorporated in the plot, there is a notable decline in the output of the manufacturing sector during the period 1993-1994 when the price of electricity went up (Figure 1.2), suggesting an increase in price may affect output of the sector.

1.3 Energy Policy in Kenya

Kenya's energy policy is documented in the Energy Act No. 4 of 2006, which contains provision for Energy Regulatory Commission (ERC), and various tribunals on petroleum and natural gas, electricity, renewable energy and energy. The energy regulatory commission was established in part two of the Act to consolidate regulatory functions in the energy sector. Some of the Commission's functions include: licensing and regulation of importation; generation, exportation and utilization of both petroleum and electricity goods and services; supervising contractual agreements between sellers and buyers of energy products and services; resolution of conflicts occurring in the energy sector; ensuring fair competition in the sector; protection of both investor and consumer interests; preparation of indicative national energy plans; and collecting and maintaining energy data.

Prior to establishment of ERC, regulation in the electricity sub-sector was done by the Electricity Regulatory Board, responsible for licensing production and distribution activities as well as electricians who set up practice in Kenya. The Commission uses the Energy Act, electricity regulations, and Least Cost Power Development Plans as regulatory instruments in the electricity sector.

The Least Cost Power Development Plans (LCPDP) is an indicative plan prepared and updated on an annual basis by ERC to inform policy makers of the electricity demand in the country, and the consequent investment requirements in both generation and transmission capacities (Government of Kenya, 2010b). As part of the development plan, a forecast model for electricity demand is prepared to inform the later stages of the plan, which include cost expansion and transmission development plans.

1.4 Statement of the Problem

Although most mainstream economic theories do not recognize energy as a critical input in the production process, the essential role of electricity in both production and consumption of goods and services within an economy is widely accepted (Payne, 2009). The Kenyan manufacturing sector is expected to increase its output by at least 10 per cent per annum to meet increasing local and foreign demand for manufactured goods and, consequently, increase employment as well as deliver other linkages in the economy (Government of Kenya, 2008).

However, according to Government of Kenya (2007b), one of the major problems facing the manufacturing sector in Kenya is inadequate and expensive electric energy. Although Kenya has embarked on heavy investment in electric power to mitigate this problem, there are existing policy proposals to subject the manufacturing firms to energy efficiency measures, in the realization that energy generation activities are contributing to climate change in an increasing manner (Government of Kenya, 2007b). The manufacturing sector is being subjected to efficiency programmes as conservative measures because of the shortage of electricity in the nation and attendant cost implications.[2] Further, the sector's production is not included in the power forecast model of Least Power Development Plan, despite the pattern displayed above between electricity consumption and output of the sector. Following the concept of causality as proposed by Granger (1988), if past consumption pattern of electricity by the manufacturing sector in Kenya is useful in predicting the future output of the sector, then the manufacturing sector is electricity-dependent and consequently, any shock in the quantity of electricity consumption would be transmitted to the output of the sector and the other linkages delivered by the manufacturing sector to the economy.

Figure 1.2 shows that electricity consumption and economic output seem to move together, but we cannot tell whether electricity consumption by the manufacturing sector stimulates output in the sector, or output in the manufacturing sector stimulates consumption of electrical energy by the sector.

Without knowing the nature of interaction, one cannot tell whether policy makers should use the trends of expected growth in the sector's production to determine and, therefore, invest in electrical energy to meet the energy needs, or use the trends in electricity consumption to predict output growth in the sector. The knowledge on potential impact of a shock in one sector or the other also remains unknown. Such information about a country's major power consumer is important to justify investment in the electrical energy sector, since failure to invest may lead to inadequate energy and subsequent limitation of activity in the sector, while over-investment leads to idle capacity, heavy sunk costs and sub-optimal utilization of resources. More importantly, lack of knowledge makes it impossible for policy makers to evaluate the potential impact of imminent energy conservation policies, or production shocks in the manufacturing sector.

Although Studies have been done on the causality of energy consumption and economic growth at both national (Odhiambo, 2009) and cross country levels (Wolde-Rufael, 2006), there are limited studies for the Kenyan case. This study will fill this gap by investigating this relationship for the Kenyan manufacturing sector - a likely recipient of shocks from policy actions in the electricity sub-sector.

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[2] See www.erc.or.ke and Government of Kenya (2006) for information on energy audits.

Existing studies on Kenya have not analysed electric power consumption by the manufacturing sector, a major power consumer accounting for 10 per cent of GDP. Further, most studies omit the power price variable, yet this may be important in explaining the relationship between electricity consumption and output in the manufacturing sector. In departure from previous studies, the price of oil will be included in the analysis, since oil is the most common substitute for electricity in the manufacturing sector.

1.5 Research Objectives

The general objective of the study is to interrogate the nature of causality between electricity consumption and economic growth for the Kenyan manufacturing sector. Specific objectives are:

- To investigate whether changes in electricity consumption can be used to predict the changes in output (and vice versa) for the Kenyan manufacturing sector
- To draw policy recommendations

1.6 Research Questions

The research questions guiding the study are:

- Is knowledge of economic output (electricity consumption) in Kenyan manufacturing sector important in predicting electricity consumption (economic output)
- What policy recommendation can be drawn from the above?

1.7 Justification of the Study

Planning for economic growth will require knowledge on the precise interaction between the economy and its electricity-consuming activities. Given that the manufacturing sector is the largest consumer of electricity in Kenya, it is important to evaluate its dependence on electricity, so as to advocate for its cushioning from developments in the electricity sub-sector, which might affect its economic performance. Moreover, if the sector is to perform its expected role in transforming Kenya into a newly industrialized country, adequate power must be availed to this sector on a timely basis. Heavy investments in the electricity sub-sector and shielding of the manufacturing firms from effects of conservative power policies can then be justified if there is evidence to point that the manufacturing sector (major consumer) is electricity-dependent and will require adequate electric energy (and on timely basis) to carry out its production activities. This study sets to generate such evidence.

2. Literature Review

2.1 Theoretical Literature

According to Berndt and Wood (1975), energy could be considered as another input in the production process like labour, capital and raw materials. Since the objective of a rational firm is to minimize the cost, a firm should choose the combination of inputs that will minimize the cost of producing a given level of output. Thus, the firms demand for energy and other inputs is derived from the demand for the firm's product. From the formal solution to such a firm's cost minimization problem, the derived demand for inputs is determined by: output, production technology, the substitution possibilities between factors of production, and the relative prices of all the factors. From this argument, it is evident that energy is essential in production, thus forming a basis for a possible relationship between consumption of electricity and output of a production entity.

The debate on the relationship between energy consumption and economic growth can be represented by three main views (Odhiambo, 2009). The first view states that economic growth causes energy consumption, implying that as the economy grows, there will be increased consumption of energy. The second view supposes that it is electricity consumption that causes economic growth, implying that an economy depends on energy for survival. Lastly, there are those of the opinion that there is no relationship between economic growth and electricity consumption, implying that the two economic aspects are independent of each other.

Notably, the nature of the relationship between energy consumption and economic growth cannot be agreed upon because different nations have different energy resources, economic structures and consumption patterns (Soytas and Sari, 2007). This difference translates to the impact of energy on the economy's output. In addition, variations across countries could emanate from the data aggregation process, if energy intensive sectors of the economy contribute little to the economy's output.

According to Odhiambo (2009), the three existing hypotheses on the relationship between electricity consumption and economic growth have specific policy implications for economies. The existence of a unidirectional causality from electricity consumption to economic growth implies that an economy is dependent on the energy sector, and any conservative measure in the energy sector will adversely affect the national economy. On the other hand, a unidirectional relationship running from economic growth to energy consumption could imply that a country may implement energy conservation policies without an adversity in the overall economy. A neutral hypothesis would imply that energy consumption and economic growth are entirely independent, and policy actions/shock on one will not be directly transmitted on to the other.

2.2 Empirical Literature

Dargay (1983) analysed the energy demand for Swedish manufacturing industry for the period 1952-1976, with the aim of finding out the price elasticity of energy demand and substitution possibilities between energy, capital and labour. Independent variables of the study comprised of labour prices, capital, and energy and production volume. The study utilized input demand functions derived from translog cost model, and Allen partial elasticity of substitution to address the objectives. The analysis included a total of 12 manufacturing sub-sectors, on which basis a system of input demand functions were estimated. The findings revealed that whereas the price elasticity of energy demand was inelastic in the pulp and paper sub-sectors, it was elastic in the primary metal sub-sector. Further, out of the twelve sub-sectors considered by the study, price elasticity of energy demand was established in only 8 of the sub-sectors. Finally, energy and capital were found to be complements in six sub-sectors, while only the food sub-sector exhibited capital energy substitutability.

Soytas and Sari (2007) examined the relationship between energy and production in the manufacturing industry of Turkey. The study carried out a multivariate analysis, including fixed investment, energy consumption, value added and labour for the manufacturing sector. The analysis was based on a Vector Error Correction Model and impulse responses and variance decomposition to confirm the causality relationship.

The results of the study revealed the existence of unidirectional causal relationship running from energy consumption to output produced, without feedback. This implies that the Turkish manufacturing industry is energy dependent and, consequently, energy conservation measures would affect the production activities of the manufacturing sector in an adverse manner.

Altinay and Karagol (2005) studied the relationship between electricity consumption and economic growth in Turkey using annual time series data for the period 1950 to 2000. The test for unit root found that the data was not an integrated process, and the usual test for Granger causality could not be carried out. Consequently, two approaches were used in testing for causality: Dolado-lutkepohl (DL) test since it does not require the time series processes to be co-integrated; and the Granger causality test, which detrended the data since the properties of the data displayed a trend pattern. If series have no integrated process, then co-integration and consequently Granger causality test cannot be performed. The study concluded that electricity consumption precedes economic growth, since causality was found to run from electricity consumption to income. As a result, electricity consumption can be used as a leading indicator of economic growth.

Tang (2008) investigated the relationship between electricity consumption and economic growth in Malaysia using quarterly time series data from 1972 to 2003. To test for the existence of a long run relationship between the two series, the error correction model – based f-test was applied. Further, the standard Granger causality and Modified Wald test were conducted to test for short and long run causality between the two variables. The study found that electricity consumption and economic growth were not co-integrated, therefore, there was no long run relationship. However, the Modified Wald test revealed that electricity consumption Granger causes economic growth. This implies that electricity consumption is an important element for the development of the Malaysian economy.

Odhiambo (2009) examined the relationship between electricity consumption and economic growth for South Africa, using a tri-variate Granger causality test and time series data for 1971-2006. Citing inherent omission of variables - errors in previous studies that limited themselves to only two variables (economic growth and electricity consumption), the study incorporated employment as an intermittent variable, and used an error correction model to capture both short and long run causality test. The results revealed a bidirectional causality running from electricity consumption to economic growth, and from economic growth to electricity consumption in the short and long run. The study also found a unidirectional causality from employment to economic growth, while no relationship was found between employment and electricity consumption. The study concluded that South Africa needed to intensify the electricity infrastructure to curb possible shortages of electricity resulting from increased industrial activities.

Ouedraogo (2009) investigated the direction of causality between electricity consumption and economic growth for Burkina Faso, using bounds testing approach to co-integration and the Granger Causality test. The variables used are Gross Domestic Product, capital formation and electricity consumption, to avoid errors due to omission of important variables. The study found a positive bi-directional relationship running from electricity consumption to economic growth, both in the short and long run. However, no significant relationship was found between electricity consumption and capital formation. The results implied that increasing energy supply and improving related infrastructure would ensure that the economy flourished, while energy conservation measures could hamper economic growth.

Akinlo (2009) studied the granger causality relationship between electricity consumption and economic growth for Nigeria for the period 1980-2006. The variables of the study were real GDP and electricity consumption. Hodrick-Prescott filter was applied in decomposition of the trend and fluctuation components of the real GDP and electricity series. The results of the unfiltered data indicate that there was a causality relationship running from electricity consumption to economic growth and not the reverse. Further, variance decomposition test was applied for 'out-of-sample causality', and the results were consistent with the findings of the error correction model (that causality runs from electricity consumption to economic growth).

In the analysis of the filtered data, the study found that the cyclical and trend components of both electricity consumption and real GDP series were co-integrated. This implies a non-restricting relationship between the two series. Causality tests on both trend and cyclical component revealed a unidirectional causality from economic growth to GDP, and the Variance Decomposition confirmed this relationship for the out-of–sample case. The results were attributed to the role of industry in economic growth, in the sense that the increasing contribution of industry to Nigeria's GDP could have led to increased electricity consumption and eventually economic growth. The study concluded that Nigeria's economy was highly electricity dependent, and negative shocks such as high energy prices and energy conservation policies would impact negatively on the country's economic growth. The results for the cyclical component revealed that electricity consumption was also an indicator of a business cycle, and changes in consumption may draw attention to an imminent business cycle.

Cheng, Lin and Chang (2010) studied the linear and non-linear relationship between electricity consumption and GDP for Taiwan using a Granger causality and Hiemstra-Jones test. Total electricity consumption was separated into its different components by main consumer category, namely: industrial and residential. With regard to the linear relationship, the study found a bidirectional relationship between total electricity consumption, industrial sector consumption and real gross national product (GDP). However, the neutrality hypothesis was not rejected, implying no causality between residential electricity consumption and real GDP. On the other hand, the non-linear model revealed bidirectional causality between total electricity consumption and real GDP, while a unidirectional relationship running from residential sector electricity consumption to real GDP was found. The study concluded that for Taiwan, increasing industrial electricity consumption and energy efficiency measures would lead to higher economic growth.

Yoo and Kwak (2010) studied the relationship between electricity consumption and economic growth for South American countries (Argentina, Venezuela, Ecuador, Brazil, Chile, Columbia and Peru) using Hsiao's version of Granger causality tests. The study utilized time series data for 1975-2006. It was found that the nature of the relationship between electricity consumption and economic growth varied from country to country. For example, while a unidirectional causality relationship running from electricity consumption to GDP per capita was found for Argentina, Brazil, Columbia and Ecuador without any feedback effects, bidirectional causality was found in Venezuela and no causal relationship was found in Peru. The study concluded that the relationship between energy consumption and economic growth is not uniform for all countries, because of the inherent differences in energy consumption structures of economies. The unidirectional relationship in Argentina, Brazil, Columbia and Ecuador implied that while electricity consumption stimulates economic growth due to related activities, an increased GDP does not lead to additional spending on electricity in those countries. The study concluded that electricity was the 'initial receptor of exogenous impact, and the adjustment to equilibrium is through the real income for the countries, with a unidirectional causality relationship (Yoo and Kwak, 2009). The reverse relationship for the case of Venezuela was attributed to increased incomes for households, who in turn increased their electricity consumption.

Wolde-Rufael (2009) studied the relationship between per capita electricity consumption and real GDP per capita for 17 African countries using annual time series data for 1971-2001. The study used Bounds test approach to co-integration and Modified Wald test for causality to avoid problems associated with misdiagnosis of non-stationarity and co-integration. Unidirectional causality running from economic growth to electricity consumption was found in Cameroon, Ghana, Nigeria, Senegal, Zimbabwe and Zambia while causality from electricity consumption to economic growth was found in Benin, Democratic Republic of Congo and Tunisia. For the case of Egypt, Gabon and Morocco, the study found evidence for bidirectional causality. However, no causality between per capita electricity consumption and economic growth was found for the case of Kenya, South Africa, Sudan, Republic of Congo and Algeria. The study's results should be interpreted with caution because electricity accounted for only 4 per cent of energy requirements in most African nations.

Akinlo (2009) carried out a study on energy consumption and economic growth for 11 Sub-Saharan countries: Kenya, Nigeria, Gambia, Zimbabwe, Togo, Senegal, Ghana, Sudan, Cameroon, Cote d'Ivore and Congo; using time series data for the period 1980-2003. The study used the Bounds testing approach to co-integration and Granger's test to establish for long-run relationship between energy consumption and economic growth. Long run relationship between energy consumption and economic growth was found for 7 countries, namely: Cameroon, Cote d'Ivore, Gambia, Ghana, Senegal, Sudan and Zimbabwe, while no such relationship was found for Kenya, Nigeria, Togo and Congo. The Granger causality test found a bidirectional relationship between energy consumption and economic growth for Gambia, Ghana and Senegal. However, economic growth was found to Granger cause energy consumption in Sudan and Zimbabwe, while no causality was found in Kenya, Nigeria and Togo. The study noted that for the countries where no causality was found, energy conservation policies should be the next concern for planners, especially if the countries belonged to the energy inefficient groups.

Wolde-Rufael (2009) investigated the causal relationship between energy consumption and economic growth for 17 African countries, in a multivariate framework consisting of GDP, energy, labour and capital. The study improved on earlier work by including other variables in addition to energy, and utilized impulse responses and variance decomposition to assess the relative importance of the causal impact of energy consumption relative to labour and capital. The introduction of these two additional factors led to a significant alteration of the results obtained by a previous study, implying that the latter could have suffered bias from omission of relevant variables. Causality was found in countries that had earlier on displayed non-causality, while the direction of causality was altered in most of the countries. The variance decomposition analysis revealed that in majority of African countries, energy is just a contributing factor to production and has lesser importance than capital and labour. This could be attributed to the fact that most African nations are labour abundant, and growth of output is largely dependent on augmentation of labour with energy and capital.

2.3 Overview of Literature

Studies have been done extensively on the relationship between energy/ electricity consumption and economic growth. The studies differ in the methodology. While some use the traditional VAR approach to co-integration and Granger causality test (which require knowledge of the order of integration of series), others use the ARDL Bounds testing procedure and modified Wald test or Modified Granger's test for causality because of the nature of their data. Moreover, Wolde-Rufael (2009) used a bi-variate analysis, which is suspect due to possibility of omitting some relevant variables in their models. Wolde-Rufael (2009) conducted multivariate analyses to avoid the errors of omission of variables. The multivariate studies ran into the problem of multiple causalities.

Some studies acknowledge that African economies exhibit different energy consumption levels and unique economic structures, hence raising the need to carry out country-specific analysis to yield information that is policy relevant to a specific country. Studies of this nature are limited for Kenya and this study seeks to fill this gap. In a departure from the previous studies whose concern is aggregate electricity consumption without separating it into component-consuming economic sectors, this study will carry out an analysis for the major consumer of electricity in Kenya, because it is the most likely recipient of any shock resulting from electricity consumption policy.

3. Methodology

3.1 Theoretical Framework

According to Baxter and Rees (1968), electricity and other forms of energy can be regarded as inputs into the production process, just like labour and capital. This study argues that although the popular view is to consider firm's demand for a particular fuel within the context of a 'whole' energy market, there is a simpler way of approaching demand for individual fuel. This method considers separate fuels as inputs into the production function, with the assumption that firms have specific demand functions for each separate fuel.

The second approach is adopted in this study since the focus of the study is individual fuel (electricity) as opposed to energy complex.

Cost minimization theory with energy inputs in industry (Baxter and Rees, 1968)

Assuming that manufacturing firms have a Cobb-Douglas technology with inputs as labour, capital, oil, gas, coal and electricity, the production function can be expressed as:

$$Q = \beta_0 x_1^{\beta_1} x_2^{\beta_2} ... x_n^{\beta_n} \quad \text{......3.1}$$

where Q is output, x_i*(i=1,2...n)* are the inputs (labour, capital, oil, coal, electricity and other fuels), and $\beta_i (i = 1, 2, ...n)$ are parameters.

The firm's objective is to minimize the total cost of production given as

$$TC = p_1 x_1 + p_2 x_2 + ... p_n x_n \quad \text{......3.2}$$

where

TC is total cost of production, and p_i*(i=1,2...n)* is the input prices (which are assumed to be given). The cost minimization problem of the firm can thus be stated as:

$$\min TC = p_1 x_1 + p_2 x_2 + ... p_n x_n$$
$$subject Q = \beta_0 x_1^{\beta_1} x_2^{\beta_2} ...... x_n^{\beta_n} \quad \text{......3.3}$$

Introducing the Lagrange multiplier (λ) gives the following solvable equation:

$$Z = p_1 x_1 + p_2 x_2 + ... p_n x_n + \lambda (Q - \beta_0 x_1^{\beta_1} x_2^{\beta_2} ... x_n^{\beta_n}) \quad \text{......3.4}$$

The results of the first order condition for a constrained cost minimization problem are given as:

$$
\begin{aligned}
\partial Z / \partial x_1 &= p_1 - \lambda\beta_1\beta_0 x_1^{\beta_1 - 1} x_2^{\beta_2} \ldots x_n^{\beta_n} = 0 \\
\partial Z / \partial x_2 &= p2 - \lambda\beta_2\beta_0 x_2^{\beta_2 - 1} x_1 \ldots x_n^{\beta_n} = 0 \\
\partial Z / \partial x_n &= p_n - \lambda\beta_n\beta_0 x_1^{\beta_1} x_2^{\beta_2} \ldots x_n^{\beta_{n-1}} = 0 \\
\partial Z / \partial \lambda &= Q - \beta_0 x_1^{\beta_1} x_2^{\beta_2} \ldots x_n^{\beta_n} = 0
\end{aligned}
\qquad \ldots\ldots\ldots\ldots\ldots\ldots(3.5)
$$

Equation 3.5 represents a system of *n+1* equations with *n+1* unknowns. If we make electricity the n^{th} input, the solution for x_n in the system of equations 3.5 above will give the firm's demand function for electricity as:

$$x_n = \phi_0 p_1^{\phi_1} p_2^{\phi_2} \ldots p_n^{\phi_n} Q^{\phi_n + 1} \ldots\ldots\ldots\ldots\ldots 3.6$$

$\phi_i (i = 0, 1, 2, \ldots, n+1$ are parameters in the firms conditional input demand function.

Thus, given the Cobb-Douglas production function, the demand for electricity is an exponential function of the output and input prices. This exponential model can then be converted into its linear form by taking the logarithms on both sides to get:

$$lx_n = \phi_0 + \phi_1 lp_1 + \phi_2 lp_2 + \ldots + (\phi_{n+1}) lQ \ldots\ldots\ldots\ldots\ldots 3.7$$

From equation 3.7, the variables that will influence electricity use in manufacturing sector are own price (the price of electricity), cross prices (the price of oil), the output and prices of other (non-energy) inputs (capital and labour).

3.2 Theoretical Model

Since the popular fuels in the Kenyan manufacturing sector are electricity and oil (Onuonga, 2008), this study will consider five factors of production, namely: labour, capital, electricity and oil. The electricity demand model derived from a linearized exponential demand function can then be given as:

$$le = \alpha_0 + \alpha_1 lq + \alpha_2 lp_e + \alpha_3 lp_l + \alpha_4 lp_o + \alpha 5 lp_k \ldots\ldots\ldots\ldots\ldots 3.8$$

where

e represents the quantity of electricity consumption

q is the output

p_e is price of electricity

p_t is price of labour

p_o is price of oil

p_k is the price of capital

3.3 Empirical Model Specification

Since Kenya is a developing country with an economic structure that cannot allow for the perfect market for labour and capital, we make some adjustments to the above theoretical model to align it with existing studies on electricity demand. Several studies (Wolde Rufael, 2009 and Soytas and Sari, 2007) use the number of employees in the manufacturing sector in their fuel demand estimation, instead of the price of labour because developing countries are known to use labour force to perform some of the activities that can be done using electricity as well, due to the wage rigidities in the labour market. Thus, replacing the price of labour with the number of employees could yield a more direct relationship, especially since information on price of labour for Kenya can only be calculated by averaging the total manufacturing sector's wage bill, with the number of employees in the sector. Further, instead of using the price of capital to explain variations in electricity consumption, empirical studies (Soytas and Sari, 2007) have employed the fixed investment because increased investment in machinery and other physical assets that use power is more likely to influence electricity consumption than the price of capital as proposed by the theoretical demand model for electricity. By modifying equation 3.8, the empirical model for the study can thus be specified as follows:

$$le = \alpha_0 + \alpha_1 lq + \alpha_2 lp_e + \alpha_3 lp_o + \alpha_4 lK_m + \alpha_5 lL_m + e_t \qquad 3.9$$

K_m is the fixed capital investment in the manufacturing sector

L_m is the employment in numbers in the manufacturing sector and the other variables for study (l_e, l_q, lp_e, lpo, lK_m, L_m).

3.4 Data, Source and Measurement of Variables

Table 3.1 explains the measurement of the variables and sources of time series (1970-2008) data that was used for the study. All the variables were converted to logarithms.

Table 3.1: Variables and their measurement

Variable		How it will be measured	Source of data
Electricity consumption by manufacturing sector	E	Sales of electricity in Kilo Watt hour to the industrial sector	Economic Survey (various issues)
Price of electricity for manufacturing sector	P_e	Price of electricity sales to industrial sector (in Ksh per kWh)	KPLC records
Price of oil	P_o	Price of oil (heavy diesel oil) per tonne	Statistical Abstract (various issues)
Labour	L	No. of employees in the manufacturing sector	Economic Survey (various issues)
Output (as a proxy for economic growth)	y	Manufacturing sector value added to GDP	Statistical Abstract (various issues)
Capital investment	K	Fixed capital formation in the manufacturing sector	Statistical Abstract (various issues)

4. Analysis, Findings and Discussion

4.1 Vector Error Correction Model

Although time series data is non-stationary (its mean and variance is non-constant), it is possible that a combination of two non-stationary time series will result into a stationary series or one integrated of a lower order. This is the case if such two variables are co-integrated. According to Engel and Granger (1987), if co-integration occurs between two or more variables, there must be an error correction mechanism governing the joint behaviour of such variables, which is expressed as a Vector Error Correction Model. In general, if y_{1t} and y_{2t} are co-integrated, the VECM is expressed as:

$$\Delta y_{1t} = \Pi_{10} + \Pi_{11} x_{t-1} + \sum_{i=1}^{p_1} \Pi_{12,i} \Delta y_{1,t-i} + \sum_{i=1}^{p_2} \Pi_{13,i} \Delta y_{2,t-i} + \varepsilon_{1t}$$
$$\Delta y_{2t} = \Pi_{20} + \Pi_{21} x_{t-1} + \sum_{i=1}^{p_3} \Pi_{22,i} \Delta y_{1,t-i} + \sum_{i=1}^{p_4} \Pi_{23,i} \Delta y_{2,t-i} + \varepsilon_{2t} \quad \text{..4.1}$$

Where Δ denotes the first order difference, $i=1...p$ represents the lag length and x_{t-1} are the adjustment parameters or disequilibrium levels of y_1 and y_2 in their previous periods.

Later in this section, we develop a vector error correction model (VECM) on the basis of which the analysis and test of hypothesis will be carried out. The first step, however, is to determine the variables that will enter the dynamic analysis (Vector Autoregression). These variables are as given in the empirical model (l_e, l_q, lp_e, lp_o, lK_m, L_m).

4.2 Unit Root Tests for Data

Time series data is known for giving spurious results if the analysis is conducted using OLS method on series that have unit roots. As a result, it is important to first pre-test data for this condition. The study used two tests, namely: Philips Perron (PP) and Augmented Dickey Fuller (ADF) to test for presence of unit root in the series. Trends were included in the test equations, if plots established that the data had a tendency to either increase or decrease over time. The results of each test on every series are shown in Appendix 8 and 9.

From the results, all variables of the study are integrated of first order. Having established this, the next logical step is to conduct a test for co-integration. The concept of co-integration implies that the variables in question may move in a divergent manner in the short run, but convergence is achieved in the long-run through an error correction mechanism that adjusts the divergent movements back to equilibrium in the long run. As a result, if we establish that the variables are co-integrated, then it can be concluded that a long run relationship exists among them. However, this test for co-integration requires that we first establish the number of lags to be used in the VAR model specification.

4.3 Lag Selection

The lag selection was carried out by first estimating the unrestricted VECM model with the maximum 5 lags allowed by the model. The study adopted one lag, which was selected by the majority of the criteria (Hannan-Quinn; Schwarz information criterion, Akaike Information Criterion and final prediction error) as shown in Table 4.1.

4.4 Cointegration Test

There are two popular tests for co-integration, namely: the Johansen Maximum Likelihood method and the Engel and Granger two-step method. The latter method has a limitation in that any error made in the first step will automatically be transferred to the second step, compromising the accuracy of the test. The Johansen test is a multivariate (system-based) test based on a VAR model to represent the dynamic process, and can thus test for the presence of multiple co-integrating vectors. The test is based on the relationship between the rank of a matrix and its characteristic roots. The number of co-integrating vectors equals the rank of a matrix. The latter is the number of non-zero characteristic roots in a matrix (Oduor, 2008). The results of the Johansen co-integration test are reported in Table 4.2.

Table 4.1: Lag order selection

VAR lag order selection criteria						
Endogenous variables: log of electricity demand (LE); log of investment (LK); log of price of electricity (LP_e); log of number of workers (LL); log of price of oil (LP_o); log of output (Ly)						
Lag	**Log L**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	19.30811	NA	1.88e-08	-0.760463	-0.493832	-0.668422
1	189.0196	271.5384*	9.35e-12*	-8.401121*	-6.534704*	-7.756834*

Table 4.2: Co-integration test

Series: Electricity consumption capital investment electricity price, labour, price of oil, output				
Lags interval (in first differences): 1 to 1				
Trace test				
Hypothesized		**Trace**	**0.05**	
No. of CE(s)	**Eigen value**	**Statistic**	**Critical Value**	**Prob.****
None *	0.808230	112.1896	95.75366	0.0023
At most 1	0.468179	56.04001	69.81889	0.3764
Trace test indicates 1 co-integrating equation at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				

Unrestricted co-integration rank test (Maximum Eigen value)				
Hypothesized		**Max-Eigen**	**0.05**	
No. of CE(s)	**Eigen value**	**Statistic**	**Critical value**	**Prob.****
None *	0.808230	56.14964	40.07757	0.0004
At most 1	0.468179	21.46927	33.87687	0.6486
Max-Eigen value test indicates 1 co-integrating equation at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				

The Johansen Maximum Likelihood test yields two statistics that point to the number of co-integrating equations: the trace and maximum Eigen value statistics. The results indicate that one co-integrating equation exists. The test for a long run (co-integrating) relationship between electricity consumption and output of the manufacturing sector gives a p-value of 0.0000 and an LR statistic of 47.56, implying that there is a unique co-integrating vector between electricity consumption, investment, price of power, employment in manufacturing sector, price of oil and output.

According to Granger (1988), if co-integration exists between two variables, then causality exists in at least one direction. Notably, if variables are co-integrated, test for causality should be performed in a Vector Error Correction Mechanism (VECM) because performing the causality test in an unrestricted VAR (first differences) will yield misleading results that lack the long run properties. Moreover, if one or more of the variables is found not to be weakly exogenous, a VECM is preferred to a single equation. Tests for weak exogeneity revealed that price of electricity, labour, price of oil and output were not weakly exogenous.

4.5 Vector Error Correction Model-Based Causality Test

According to Odhiambo (2009), a Vector Error Correction Model-based test for causality not only allows one to establish the direction of causality amongst variables, but also makes it possible to differentiate between long-run and short-run Granger causality.

While the long-run Granger causality relationship is measured through the significance of the t-test of the lagged error correction terms, the short-run causality is measured through the F-statistics and significance of the lagged changes in the independent variables (Odhiambo, 2009).

The error correction model on which the Granger causality test for the study was conducted is stated as follows:

$$\Delta lE_t = \lambda_0 + \sum_{i=1}^{q} \lambda_{1i} \Delta lE_{t-i} + \sum_{i=1}^{r} \lambda_{2i} \Delta lK_{t-1} + \sum_{i=1}^{r} \lambda_{3i} \Delta lP_{et-i} + \sum_{i=1}^{r} \lambda_{4i} \Delta lL_{t-i} + \sum_{t=i}^{r} \lambda_{5i} \Delta lp_o$$
$$+ \sum_{i=1}^{r} \lambda_{6i} \Delta ly_{t-i} + \lambda_7 ECM_{t-1} + v_t \quad \text{......} 4.1$$

$$\Delta lK_t = \varphi_0 + \sum_{i=1}^{q} \varphi_{1i} \Delta lE_{t-i} + \sum_{i=1}^{r} \varphi_{2i} \Delta lK_{t-1} + \sum_{i=1}^{r} \varphi_{3i} \Delta lP_{et-i} + \sum_{i=1}^{r} \varphi_{4i} \Delta lL_{t-i} + \sum_{t=i}^{r} \varphi_{5i} \Delta lp_o$$
$$+ \sum_{i=1}^{r} \varphi_{6i} \Delta ly_{t-i} + \varphi_7 ECM_{t-1} + m_t \quad \text{......} 4.2$$

$$\Delta lP_{et} = \alpha_0 + \sum_{i=1}^{q} \alpha_{1i} \Delta lE_{t-i} + \sum_{i=1}^{r} \alpha_{2i} \Delta lK_{t-1} + \sum_{i=1}^{r} \alpha_{3i} \Delta lP_{et-i} + \sum_{i=1}^{r} \alpha_{4i} \Delta lL_{t-i} + \sum_{t=i}^{r} \alpha_{5i} \Delta lp_o$$
$$+ \sum_{i=1}^{r} \alpha_{6i} \Delta ly_{t-i} + \alpha_7 ECM_{t-1} + n_t \quad \text{......} 4.3$$

$$\Delta lL_t = \beta_0 + \sum_{i=1}^{q} \beta_{1i} \Delta lE_{t-i} + \sum_{i=1}^{r} \beta_{2i} \Delta lK_{t-1} + \sum_{i=1}^{r} \beta_{3i} \Delta lP_{et-i} + \sum_{i=1}^{r} \beta_{4i} \Delta lL_{t-i} + \sum_{t=i}^{r} \beta_{5i} \Delta lp_o$$
$$+ \sum_{i=1}^{r} \beta_{6i} \Delta ly_{t-i} + \beta_7 ECM_{t-1} + g_t \quad \text{......} 4.4$$

$$\Delta lP_{ot} = \delta_0 + \sum_{i=1}^{q} \delta_{1i} \Delta lE_{t-i} + \sum_{i=1}^{r} \delta_{2i} \Delta lK_{t-1} + \sum_{i=1}^{r} \delta_{3i} \Delta lP_{et-i} + \sum_{i=1}^{r} \delta_{4i} \Delta lL_{t-i} + \sum_{t=i}^{r} \delta_{5i} \Delta lp_o$$
$$+ \sum_{i=1}^{r} \delta_{6i} \Delta ly_{t-i} + \delta_7 ECM_{t-1} + y_t \quad \text{......} 4.5$$

$$\Delta ly_t = \theta_0 + \sum_{i=1}^{q} \theta_{1i} \Delta lE_{t-i} + \sum_{i=1}^{r} \theta_{2i} \Delta lK_{t-1} + \sum_{i=1}^{r} \theta_{3i} \Delta lP_{et-i} + \sum_{i=1}^{r} \theta_{4i} \Delta lL_{t-i} + \sum_{t=i}^{r} \theta_{5i} \Delta lp_o$$
$$+ \sum_{i=1}^{r} \theta_{6i} \Delta ly_{t-i} + \theta_7 ECM_{t-1} + x_t \quad \text{......} 4.6$$

The null hypotheses about Granger causality between electricity consumption and output of the manufacturing sector can be stated as:

Hypothesis one: output in the manufacturing sector does not Granger cause electricity consumption

$$h_0 : \lambda_{6i} = 0; \lambda_7 \neq 0$$

Hypothesis two: electricity consumption in the manufacturing sector Granger causes output in the manufacturing sector.

$$h_o : \theta_{1i} = 0; \theta_7 \neq 0$$

4.6 Discussion of VECM Results

From the output in Table 4.3, the first null hypothesis that output in the manufacturing sector does not Granger cause electricity consumption in the long run is rejected (p-value of 0.005), while the second null hypothesis that electricity consumption does not Granger cause output cannot be rejected at the conventional levels of significance (calculated p-value of 0.6). The findings imply that there exists, in the manufacturing sector, a long run unidirectional causal relationship

Table 4.3: VECM Results

Variables in equation	**Dependent variable**					
	Electricity consumption	Investment	Price of electricity	Labour	Price of oil	Output
Constant	0.021 (0.669)	0.090 (1.261)	0.067 (0.969)	0.030 (3.29)	0.169 (1.973)	0.075 (2.025)
Change in electricity consumption	0.227 (1.242)	0.496 (1.213)	-0.020 (0.051)	-0.025 (-0.478)	-0.546 (-1.118)	-0.111 (-0.523)
Change in investment	0.139 (1.342)	0.038 (0.167)	0.116 (0.514)	-0.006 (-0.222)	0.221 (0.797)	0.290 (2.392)*
Change in price of electricity	-0.183 (-.388)	-0.122 (-0.416)	0.020 (0.072)	0.043 (1.130)	-0.032 (-0.093)	-0.131 (-0.850)
Change in labour	-0.379 (-0.796)	-0.062 (-0.058)	-0.443 (-0.428)	-0.111 (-0.803)	-0.416 (-0.328)	0.188 (0.340)
Change in price of oil	0.209 (2.918)*	0.014 (0.089)	-0.093 (-0.600)	0.010 (0.524)	-0.040 (-0.212)	0.006 (0.075)
Change in output	0.025 (3.013)**	0.178 (0.413)	0.173 (0.413)	-0.004 (-0.082)	-0.080 (-0.156)	0.199 (0.888)
ECM(-1)	-0.385 (-2.583)*	-0.344 (-1.034)	0.379 (1.169)	0.094 (4.477)*	0.057 (0.143)	0.080 (0.460)
F-statistic	2.208***	0.346	0.536	4.068*	0.343	2.282***
R^2	0.37	0.085	0.126	0.522	0.084	0.256
*, ** and *** denotes significance at 1%, 5% and 10 %, respectively						

running from output growth to electricity consumption without feedback effects and supported by the negative and significant error correction term. This means that output Granger causes electricity consumption, but electricity consumption does not Granger cause output in the manufacturing sector. Further, past information about the output of the manufacturing sector is important in predicting the changes in electricity consumption of the sector, but one cannot rely on the past information of electricity consumption to predict the output of the sector. These findings contradict Soytas and Sari (2007) who found a unidirectional causal relationship running from energy consumption to value added of the Turkish manufacturing sector.

Other findings indicate that investment in capital Granger causes output in the manufacturing sector (with a p-value of 0.02), implying that output in the Kenyan manufacturing sector is investment-led. It is therefore possible to predict the output of the manufacturing sector by having information on the capital investment pattern in the sector, and any shocks leading to an increase in investment in the manufacturing sector will be transmitted to the output. The price of oil was also found to Granger cause electricity consumption in the manufacturing sector. This could be explained by the fact that most manufacturing firms in Kenya use generators as backup plan when they are put out of national grid electricity supply during load-shedding programmes. An increase in price of oil could lead to increased utilization of electricity as firms switch from generator to grid electricity power source.

5. Conclusion and Policy Recommendations

5.1 Conclusion

This study examines the nature of the inter-temporal causal relationship between electricity consumption and output of the manufacturing sector in Kenya. Borrowing from previous and similar empirical studies, the study opted to carry out a multivariate analysis as opposed to bi-variate because of the inherent possibility of omitting some relevant variables. The series was found to be unit root processes integrated of first order, and a single co-integrating relationship between the variables of the study was established. Having found co-integration among the variables, a Vector Error Correction Model was used to carry out a test for long run relationship between the variables of the study and later to perform Granger causality test, because some variables were found to be endogenous in the model.

The study found a unidirectional long run causal relationship running from growth of output of the manufacturing sector to the electricity sector, implying that having information about the growth of output of the manufacturing sector would greatly help in predicting the electricity requirement of the sector. The other implication of the findings is that implementation of temporary electricity conservation policies does not affect the output of the manufacturing sector, since the latter's output is not electricity-dependent. This later finding could partly be attributed to data used for the study. While the use of electricity from the national grid is documented, data on the amount of own-generated power by manufacturing firms is not captured, yet output production depends on this power. Thus, electricity use by manufacturing firms in Kenya is under-estimated. However, it is also worthy to note that load shedding is a seasonal phenomenon and manufacturers may be able to compensate for missed production targets once load shedding programmes are terminated. It is therefore imperative that capturing of this data be undertaken by the national statistical system for effective policy analysis.

5.2 Policy Recommendations

The study recommends that ERC in partnership with the Ministry of Industrialization should closely monitor the expected changes in the quantity and type of the manufacturing sector's output, and incorporate that information in their electricity demand forecast model of the Least Cost Power Development Plans. This is because the forecast model is the basis of which investment decisions in the power sector is made, and it is thus imperative that the model includes significant causes of changes in electricity consumption, such changes in output of the manufacturing sector. This will ensure that Kenya produces enough electricity on timely basis to meet the demand of the nation.

It is also proposed that sectoral modelling for electricity demand be adopted because this would improve accuracy of predicted power needs and effectiveness of policy that targets consuming sectors.

Finally, given the expected increase in electricity requirements and the limited energy resources available in the country, the study recommends implementation of energy (electricity) audits as an efficiency policy by the Energy Regulatory Commission (ERC) in partnership with the manufacturing fraternity in Kenya. This is because any shocks that may be due to reduced consumption occasioned by such efficiency/ conservative measures will not be translated into reduced output of the manufacturing sector. In addition, operation costs will reduce, making it more competitive in the domestic and world trade arena.

5.3 Areas for Further Study

A study on the determinants of electricity demand in the major consuming sectors should be conducted to inform sectoral electricity demand forecast models. Also, there is need for a study at firm level to determine energy utilization in the manufacturing firms, since existing studies suffer from data issues.

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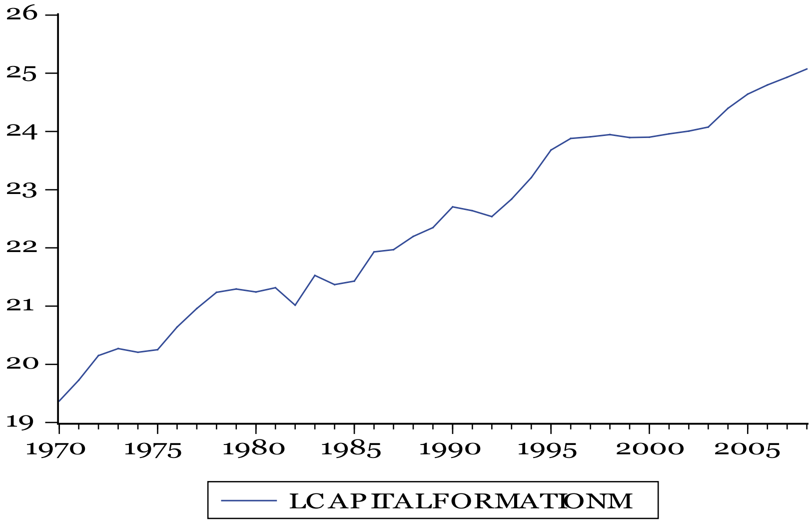
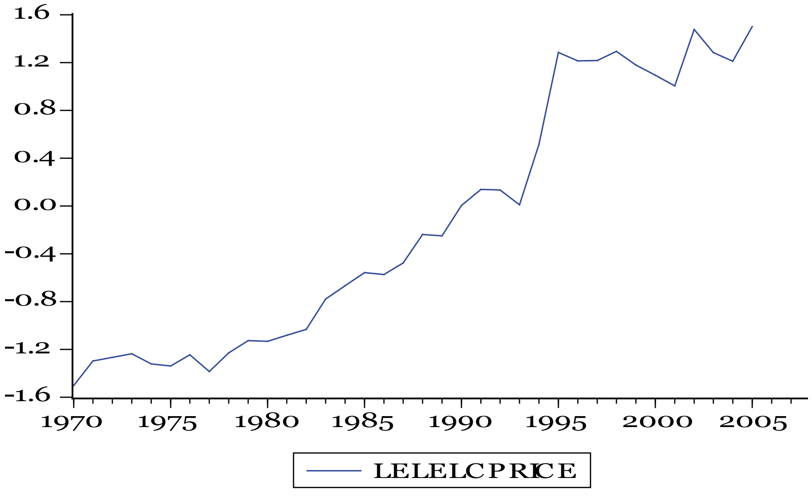
Appendix

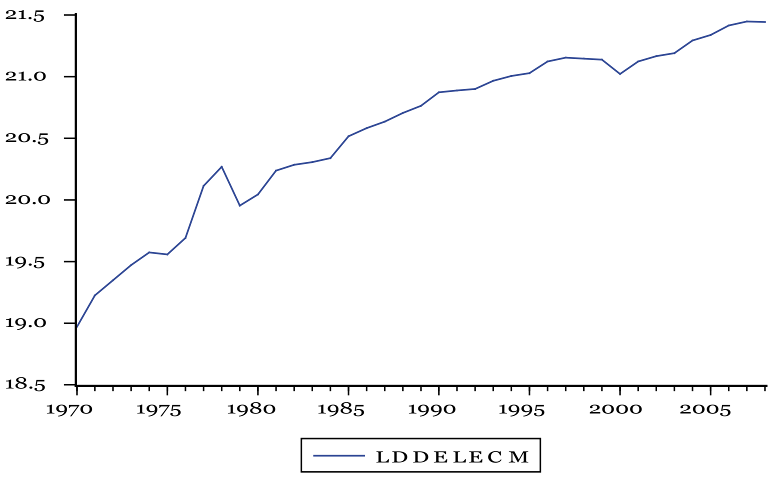
Appendix 1: Log of investment



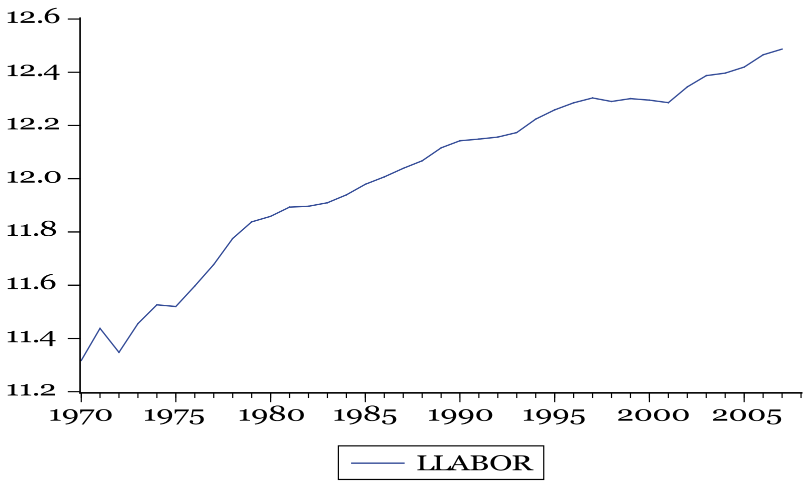
Appendix 2: Log of electricity price



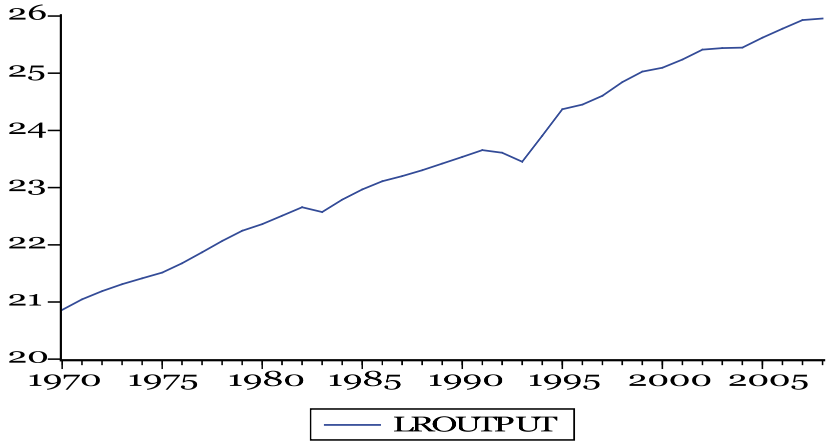
Appendix 3: Log of electricity consumption



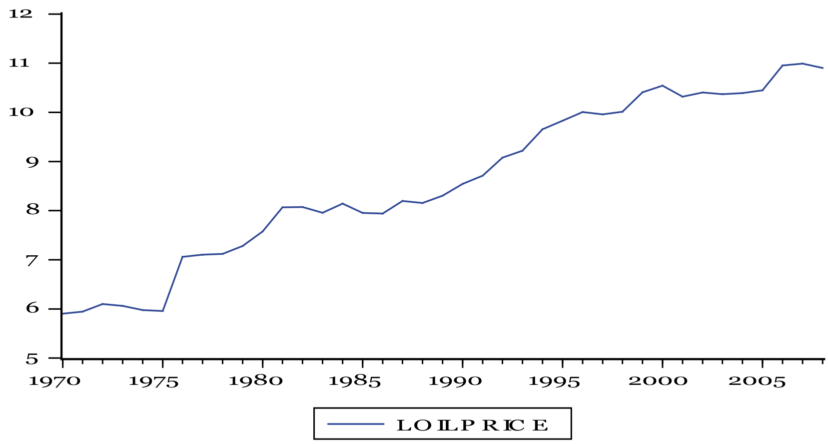
Appendix 4: Log of labour price



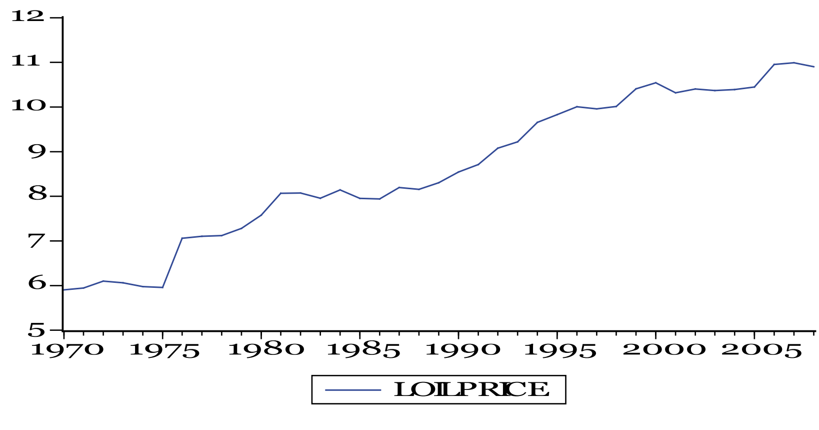
Appendix 5: Log of manufacturing output



Appendix 6: Log of oil price



Appendix 7: Log of capital investment



Appendix 8: ADF test for unit root

ADF test at levels (Null hypothesis: series non stationary)						
Variable	**Critical t**	**1%**	**5%**	**10%**	**p-value**	**Decision**
Investment	-3.03	-4.21	-3.53	-3.19	0.14	Non-stationary
Manufacturing output	-2.57	-4.21	-3.53	-3.19	0.29	Non-stationary
Oil price	-2.40	-4.21	-3.53	-3.19	0.36	Non-stationary
Electricity price	-2.30	-4.24	-3.54	-3.20	0.42	Non-stationary
Labour price	-2.10	-4.22	-3.53	-3.20	0.52	Non-stationary
Elec. consumption	-2.77	-4.21	-3.53	-3.19	0.21	Non-stationary
ADF test at first difference						
Investment	-5.87	-3.62	-2.94	-2.61	0.00	Stationary
Manufacturing output	-6.10	-3.62	-2.94	-2.61	0.00	Stationary
Oil price	-6.17	-3.62	-2.94	-2.61	0.00	Stationary
Electricity price	-5.18	-3.64	-2.95	-2.61	0.00	Stationary
Labour	-7.61	-3.62	-2.94	-2.61	0.00	Stationary
Electricity consumption	-6.64	-3.62	-2.94	-2.61	0.00	Stationary

Appendix 9: PP test for unit root

PP test at levels (Null hypothesis: Series non-stationary)						
Variable	**Critical t**	**1%**	**5%**	**10%**	**p-value**	**Decision**
Investment	-3.03	-4.21	3.53	-3.19	0.14	Non-stationary
Manufacturing output	-2.67	-4.21	-3.53	-3.19	0.25	Non-stationary
Oil price	-2.40	-4.22	-3.53	-3.19	0.36	Non-stationary
Electricity price	-2.27	-4.24	-3.54	-3.20	0.43	Non-stationary
Labour price	-2.03	-4.22	-3.53	3.20	0.56	Non-stationary
Elec. consumption	-3.00	-4.219	-3.533	-3.198	0.14	Non-stationary
ADF test at first difference						
Investment	-5.95	-3.62	-2.94	-2.61	0.00	Stationary
Manufacturing output	-5.74	-3.62	-2.94	-2.61	0.00	Stationary
Oil price	-6.27	-3.62	-2.94	-2.61	0.00	Stationary
Electricity price	-5.58	-3.63	-2.95	-2.61	0.00	Stationary
Labour price	-7.34	-3.62	-2.94	-2.61	0.00	Stationary
Electricity consumption	-5.804	-3.621	-2.943	-2.61	0.00	Stationary

Appendix 10: Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test for unit root

KPSS test at levels (Null hypothesis: series is stationary)					
Variable	**LM statistics**	**1%**	**5%**	**10%**	**Decision**
Investment	0.05	0.216	0.146	0.119	Stationary
Manufacturing output	0.075	0.216	0.146	0.119	Stationary
Oil price	0.118	0.216	0.146	0.119	Stationary
Electricity price	0.202	0.216	0.146	0.119	Non stationary
Labour price	0.207	0.216	0.146	0.119	Non stationary
Elec. consumption	0.310	0.216	0.146	0.119	Non stationary
KPSS test at first difference					
Lending rate	0.083	0.216	0.146	0.119	Stationary
Electricity price	0.064	0.216	0.146	0.119	Stationary
Labour price	0.149	0.216	0.146	0.119	Non stationary
Electricity consumption	0.081	0.216	0.146	0.119	Stationary

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ISBN 9966 777 91 1