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Causality between Disagregated Energy Consumption and Manufacturing Growth in Kenya: an Empirical Approach

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Abstract
Besides labour and capital, energy is a critical factor of economic production worldwide. In the circumstances, the role that it plays in policy regimes designed for fast and efficient economic growth cannot be overemphasized. However causality between energy consumption and manufacturing growth is not known in Kenya. Therefore, the study provides analyses of causality between disaggregated energy consumption (electricity and petroleum) and manufacturing growth using data from Kenya between 1970-2010. An integration and cointegration test shows that the variables are $I(1)$ and cointegrated. As a result, the granger causality error correction test was conducted and it indicated that there is granger causality from electricity and petroleum consumption to manufacturing in short and long run periods, and bidirectional causality between manufacturing and electricity consumption in both runs. Thus, the manufacturing sector requires electricity for economical operation. On the other hand, the lack of causality from manufacturing to petroleum consumption is attributed to the fact that very few manufacturing industries in Kenya significantly depends on petroleum because of its cost and price volatilities. Fossil energy cost impacts adversely on prices of manufactured products, consequently making Kenya's manufacture to be less competitive in the regional markets. Poor competition is one major reason for the widespread migration of the manufacturing firms to hydro-energy based technologies in Kenya. Therefore, change in manufacturing technology may significantly change petroleum consumption patterns in Kenya. However, given that there are good indications of petroleum potential within the country, the trend may reverse.
Key Words: Energy consumption; Manufacturing growth; Cointegration; Granger causality; Kenya

1.0 Introduction

Besides labour and capital, energy is considered a critical factor of production worldwide. In the circumstances, the role that it plays in policy regimes that is designed for fast and efficient economic growth cannot be overemphasized. According to Pokharel, (2006), and Erbaykal, (2008), energy plays a very important role in economic production and therefore, manufacturing growth. However, the importance of energy only came to be known during the first global oil crisis experienced in 1970s. And since then the relationship between energy and economic growth is of immense interests to economists and policy makers in designing good policy regimes for fast and efficient economic growth. Kraft and Kraft (1978) presented the first seminal paper on the relationship between energy consumption and economic growth in the United States of America (USA) and since then a number of studies emerged on the area of energy-growth nexus and panacea. However, the past studies focused on the total energy consumption and total Gross Domestic Product (GDP) growth with a few focusing on the relationship between the disaggregated energy and sectoral growth notably the outcomes are largely mixed. Moreover, they concentrated outside Africa with very little known in Kenya. The scanty studies on Kenya have focused on either total energy consumption or consumption of electricity and again given mixed results. Meanwhile apart from electricity being an important commercial energy, petroleum energy is equally an important component in the country's energy consumption mix. This study examines the causality between disaggregated energy consumption (electricity and fossil consumption) and manufacturing growth in Kenya.
The manufacturing sector accounts for approximately 10 percent of Kenya's gross domestic product (GDP). The sector's output grew at an average rate of 8 percent per annum between 1970 and 2005. The growth of manufacturing was associated with the greater use of inputs, including energy. In the government's planning document, Kenya Vision 2030, the manufacturing sector is expected to continue contributing 10 percent annually to Kenya's GDP. The manufacturing sector mainly uses electricity and oil as sources of energy in its production processes, distribution, and transport services. The utilization of these two forms of energy, on average, has been rising, resulting in increased costs in terms of energy and total production.

The manufacturing sector is the third largest energy end user in the Kenyan economy. It is the second largest user of petroleum products, after the transport sector, and the largest consumer of electricity. However, few studies have been undertaken that focus on energy demand in the manufacturing sector.

Most manufacturing activity is concentrated around the three major urban centers in Kenya: Nairobi, Mombasa, and Kisumu. The major sub-sectors within the manufacturing sector include food-processing (such as grain milling, beer production, and sugarcane crushing), paper production, textile and apparels, pharmaceutical and medical equipment, building construction and mining, and chemical and chemical-related industries. Kenya has an oil refinery that processes imported crude petroleum into petroleum products, mainly for the domestic market. In addition, a substantial and expanding informal sector engages in small-scale manufacturing of household goods, motor vehicle parts, and farm implements.

Some of the manufacturing processes use industrial diesel oil and fuel oil for their thermal energy requirements. Many processes also utilize electricity for drying, grading, and packing. A significant fraction-mostly in food processing-relies on wood fuel. The recent rise in the cost of industrial diesel oil and fuel oil, coupled with an unsustainable supply of wood fuel, particularly in the smallholder tea sector, now directly threatens the operations of many companies and the livelihood of thousands of employees. The supply of electricity to the sector is commonly rationed, especially during the dry season since most of the country's electricity is hydro-based. The result is that the Kenyan manufacturers incur losses in production, sales, damaged equipment from power surges, and overall efficiency losses caused by power interruption and uncertainty. Given the challenges of this situation to the manufacturing industry in Kenya, we sought to further the research on this subject by investigating the relationship between disaggregated energy consumption and manufacturing growth in short and long run periods in Kenya.

2.0 Literature review

Overally, a number of empirical studies (Tintner et al., 1974; Kraft and Kraft,1978; Berndt and Wood, 1979; Erol, U. and Yu, E., 1987; Masih, A. and Masih R.,1997; Stern, I. 2010; Onuong'a S. M., 2012 among others) which have been undertaken to explain the energy-economic growth nexus have given very inconsistent outcomes. The inconsistencies of the outcomes pose challenge in policy formulation for fast and efficient economic growth and therefore manufacturing growth. The following are reflections gathered on Kenya to showcase the inconsistencies of empirical evidence on the energy-growth nexus and panacea. Wolde-Rufael, (2006), studied granger causality between economic growth and energy consumption in Kenya using time series data from 1971 to 2006 in a Toda Yamamoto Granger causality model, he reported no causality. Esso, (2010), did a study on causality between energy consumption and economic growth in Kenya by use of time series data from 1970 to 2007 in a threshold cointegration approach, the results showed no granger causality between the variables. Odhiambo, (2010) carried out a similar study, that is the analysis of relationship between energy consumption and economic growth in Kenya using data from 1971 to 2006 in ARDL bounds test procedure, the study reported no causality between the variables. On the other hand, Onuong'a, (2012), carried out a study on the granger causality between energy consumption and economic growth in Kenya using data from 1970-2005 in a granger causality error correction model. The study reported causality from economic growth to energy consumption. In the existing body of knowledge, none explains the relationship between disaggregated energy consumption and performance of the manufacturing sector in Kenya. The purpose of disaggregating energy resources is to report on the role of commercial energy mix on manufacturing growth in Kenya.

To understand the role of energy on manufacturing growth, we faulted the mainstream economic growth theories; (the classical and the neo-classical) for ignoring the role of energy in the economic production yet, the literature on ecological/resource economics suggests a central role that energy plays in driving economic production. To integrate the classical, Neo-classical and the ecological theories, Stern, (2011) proposed for a modification of Solow's growth model. In the model Stern (*ibid*) added an energy input that has low substitutability with capital and labor, while allowing the elasticity of substitution between capital and labor to remain at unity. In this model, depending on the availability of energy and the nature of technological change, energy can be either a constraint on growth or an enabler of growth. Omitting time indexes for simplicity, the model incorporates energy as a homogeneous variable and defines the growth function as follows;

$$Y_i = f(A \quad X_i \quad E_j) \qquad [1]$$

Where; Y_i a vector of outputs (in our case, it represents manufacturing outputs), X_i a vector of inputs (for example labour, human capital and stock of Capital) and E_j a vector of energy resources (such as fossil fuel and electricity) and *A* is the state of technology which define the total factor productivity indicator. There from, we augment the general economic growth model with different coefficients as follows;

$$Y_t = AK_t^{\alpha} \quad L_t^{1-\alpha} \quad E_{it}^{\beta} \qquad [2]$$

$0 < \alpha \quad 1-\alpha \leq 1$

$0 < \beta \leq 1$

$\forall t = 1,2,3................Nth$ time and

$\forall i = 1,2,3.................Mth$ vector of energy.

Equation (2) embeds a Cobb-Douglas production function of capital (K) and labor (L) in a constant return to scale (CRTS) function and energy (E) that produces gross output Y overtime.

Empirical analyses of Stern (2000), Lee and Chang (2008) and Constantini *et al* (2010) beheld that energy is a distinct variable of economic production. They underscored the complementarity of energy to labour and capital in production. Consequently, the relationship between economic production and energy consumption is reformulated as a distinct factor of production in a formation:

$$Y_t = f(AE_{it}) \qquad [3]$$

Contrary to mainstream economic growth theories which assume that resource consumption is a consequence, not a cause, of growth, Aqeel, (2001) and Lee, *et al* (2008), proposed to redefine the relationship and to consider energy resource consumption as may be a cause or consequence of growth. This was on the basis that: first, energy is an endogenous variable of economic growth and second, its consumption may be determined by the technical factor (δ) of growth. We therefore specify the linkage in a general energy consumption equation as follows:

$$E_{it} = f[Y_t \quad \delta(Y_t)] \qquad [4]$$

Where, energy consumption (E_t) at time t is a function of economic growth (Y_t) over time t and a technical factor (δ) of economic growth. The $\delta(Y_t)$ is an equivalent of the technical factor productivity A. Thus, the equation is simplified as:

$$E_{it} = f(AY_t) \qquad [5]$$

The relationship between energy consumption and economic production abovementioned; show elements of simulteneous behaviour between the energy consumption and macroeconomic growth (Eq-3 and Eq-5). Such behaviour in macroeconomic research elicits the desire to investigate the causality in short run and long run periods for policy formulation.

To understand the granger causality for appropriate policy formulation, a multivariate model incorporating a disaggregated energy inputs (electricity and petroleum consumption) is formulated. Thus, the study specified a three-equation VEC model in the Sims, (1972) format;

$$z_t = \begin{Bmatrix} w_t \\ x_t \\ y_t \end{Bmatrix} \varepsilon_t = \begin{Bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{Bmatrix} \qquad [6]$$

The Sims approach is adopted because of its profound success in previous empirical studies (Ebohon, 1996; Jumbe, 2004; Erol, 1987; Akilno, 2008 and Odhiambo, 2010). To capture both short run and long run equilibrium the approach is augmented with the error correction term and formulated as follows:

$$z_t = \begin{Bmatrix} w_t \\ x_t \\ y_t \end{Bmatrix} + \mu \begin{Bmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \end{Bmatrix} \varepsilon = \begin{Bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{Bmatrix} \qquad [7]$$

2.3 Specifications of VEC Model

The vector error correction (VEC) model for the Granger causality is specified in series for: manufacturing (MNFG) growth, electricity consumption (ELC) growth and Petroleum (PET) consumption growth.

$$\Delta \ell n \begin{bmatrix} MNFG_t \\ ELC_t \\ PET_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{bmatrix} + \sum_{k=1}^{k} \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \\ \beta_{31} & \beta_{32} & \beta_{33} \end{bmatrix} \Delta \ell n \begin{bmatrix} MNFG_{t-k} \\ ELC_{t-k} \\ PET_{t-k} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \end{bmatrix} \begin{bmatrix} \varepsilon_{1t-i} & \varepsilon_{2t-i} & \varepsilon_{3t-i} \end{bmatrix} + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \end{bmatrix}$$

[8]

In equation [8], the electricity consumption and petroleum consumption granger causes MNFG growth if their coefficients $(\beta_{12}\beta_{13})$ are significantly different from zero. But, MNFG growth granger causes electricity consumption or petroleum consumption if the coefficients of GDP growth β_{21} and β_{31} will be significantly different from zero while F-statistic test reports the joint null hypothesis that the coefficients are equal to zero.

3.0 Data and Methodology

In order to estimate granger causality, the study used the following macroeconomic data: manufacturing per capita growth, electricity consumption per capita and petroleum consumption per capita in Kenya from 1971 to 2010. The data is sourced from the World Bank country specific development indicators. The study executed the following normality and stability tests: Jargue-Bera test for normality of the data, the Augmented Dickey Fuller test and Phillip-Perron test for stationarity and the Johansen's trace test and maximum Eingen's value test for cointegration between the variables: lastly, the standard granger causality test was augmented with error correction terms (ECTs) to establish both the causality and long run relationship between energy consumption and economic growth in Kenya.

4.0 Analysis and discussions

4.1 Normality tests

Notably, non-normality of economic variables among other effects may be associated with the presence of outliers. It is therefore important, before embarking on empirical investigations, to examine whether or not the data exhibits normality. Therefore, the study adopted three normality tests: test for skewness in the distribution, test for kurtosis distribution and finally test for Jarque-Bera distribution statistic which is a combination of the skewness test and the kurtosis tests. The skewness of a symmetric distribution, such as the normal distribution is expected to be zero. Positive skewness means that the distribution has a long right tail and negative skewness implies that the distribution has a long left tail. According to the findings (appendix, table 1), while changes in the MNFG (-0.027), ELC (0.425), are normally distributed with slight negative and positive skew, meaning that extreme changes were not recorded in the observed period. PET (1.47) is border line normally distributed with a positive skew. Thus, the study concluded that the variables are a symmetric. Therefore, we reject the null hypothesis that the variables are not normally distributed around their mean. On the other hand, Kurtosis distribution of the variables which is a measure of the levels of peak or flatness of the distribution of the series around their mean was determined. Normally the kurtosis of a normal distribution is 3. If the kurtosis exceeds 3, the distribution is leptokurtic relative to the normal; if the kurtosis is less than 3, the distribution is platykurtic relative to the normal. The distribution of MNFG (2.07) and PET (3.942) are borderline leptokurtic to the normal while the distributions of ELC (2.97) is borderline less than 3 meaning its distribution is relatively platykurtic to normal. Again, the kurtosis analysis shows that there are no extreme variations in the distributions relative to the normal. A further consideration of the distribution of the variables around the mean was done by Jarque-Bera test statistic. The test statistic measures the difference of the skewness and kurtosis of the series with those from the normal distribution. The reported results show that the probability of Jarque-Bera statistic exceeds the observed values. A small probability value leads to the rejection of the null hypothesis of normal distribution. Observably, all the variables were significantly different from zero in their absolute values. We therefore reject the null hypothesis to accept that all variables are normally distributed at the 0.05 significance level.

4.2 Tests for Unit Root

Since, a VEC specification requires that some or all the variables are integrated of order one, the study investigated the status of the stationarity of the variables. In order to have more conclusive results we adopted the following three different unit root tests (using E-views 6): Augmented Dickey-Fuller (ADF) test of 1988 and Phillips-Perron (PP) unit root tests of 1988. The unit root tests were to test a null hypothesis that the series in question have unit roots: $H_0 : \delta = 0$. In all cases, a constant and a linear trend were included to represent the most general specification (See, Table 2). Augmented Dickey Fuller (ADF) tests at Log-Level show that the values for all the variables: Log (GDP), Log (ELC) and Log (PET) have unit roots. The t-statistic values are greater than the critical t-values and their associated one sided *p*-values are significantly different from zero so then we accept the null hypotheses.

Table 1: ADF - Unit Root test results

	ADF				PP			
	Unit Root on LOG-LEVEL							
	GLS t-Stat	Critical Values		Prob*	GLS t-Stat	Critical Values		Prob*
Variables		1%	5%			1%	5%	
MNFG	-1.24	-3.61	-2.94	0.643	-3.788	-3.61	-2.93	0.006
ELC	-2.07	-3.61	-2.93	0.254	-2.035	-3.61	-2.93	0.271
PET	0.664	-3.61	-2.93	0.989	-1.434	-4.21	-3.52	0.834
	Unit Root on DLOG(first difference)							
MNFG	-6.56	-3.61	-2.94	0.0000	-6.28	-3.61	-2.941	0.0000
ELC	-5.41	-3.61	-2.94	0.0001	-5.42	-3.61	-2.941	0.0001
PET	-4.69	-3.61	-2.94	0.0005	-4.49	-3.61	-2.941	0.0009

df=2
*t-Stat**- Adjusted t-Stat*
Prob- MacKinnon (1996) p-values*

According to ADF, the series are non-stationary at levels but stationary at first difference - $I(1)$, their associated one sided *p*-values are all less than critical values at both 1% and 5%. To cross-check the stationarity, we conducted the Philips-Perron (PP) test. The interpretation of the reported results is that the t-statistic values are greater than the critical t-values and their one sided *p*- values are all less than critical values at both 1% and 5%, so then we confirm the acceptance of the null hypothesis. The series are therefore non-stationary at Levels but become stationary at their first difference. The variables are therefore integrated of order one $I(1)$. Given that the series are stationary at first differences by the two techniques (ADF and PP), we reject the null hypothesis and accept the hypothesis that the series are integrated of order one.

4.3 Test for cointegration

Given that the variables are $I(1)$ and are non stationary at levels, it is imperative to explain the cointegration properties of the variables in order to facilitate granger causality test. Cointegration means that even though individual variables may be non stationary at levels but are stationary in difference, a linear combination of two or more of such series may be stationary at levels.

Such occurrence suggests the existence of a long run relationship or equilibrium between the variables (Gujarati and Sangeetha, 2007). In that respect, we adopted the Johansen cointegration method to test for cointegration between the variables. The Johansen cointegration method is popular for giving reliable results using two tests: Johansens trace test and the Johansens Maximum Eigen's value test. The two methods tests for the existence of cointegration and the number of cointegrating vectors. The interpretation of the variables is based on the critical values of MacKinon-Haug-Michelis (1999) as provided for by EViews 6 software. The test for cointegration is pegged on the null hypothesis that there is no cointegration vectors' driving the series $H_0 : \phi = 0$.

Table 3: Johansens Cointegration Test results

Variables	Unrestricted Cointegration Rank Test (Trace)					Unrestricted Cointegration Rank Test (Max E.value)			
	H0: No. of CE(s)	E.value	Trace Stat	0.05 C. Value	Prob.**	E.value	Max-E Stat	0.05 C.Value	Prob.**
Series: LOG(MNFG)	None *	0.7713	102.6971	29.797	0.0000	0.7713	54.5877	21.13162	0.0000
LOG(ELC)	At most 1 *	0.6048	48.1093	15.494	0.0000	0.6049	34.3561	14.2646	0.0000
LOG(PET)	At most 2 *	0.3104	13.7532	3.8414	0.0002	0.3104	13.7533	3.841466	0.0002

* denotes rejection of the null hypothesis at the 0.05 level (there is no cointegration)
Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05

level
**MacKinnon-Haug-Michelis (1999) p-values
Based on results reported in Table 3; both tests points out to at least three cointegrating equations at 0.05 levels of confidence for all the series of the vector equation. Engle and Granger (1987) and Granger (1988) noted that if two time series variables are cointegrated, then at least one-directional granger causation exists. The existence of a stable long-run relationship (cointegrating relationship) between the variables implies that the variables are causally related at least in one direction. Put simply that either variable may contain important information regarding another. We, then, reject the null hypothesis and conclude that there are cointegrating vectors. The presence of unit roots at levels and cointegrating equations is a sufficient condition to investigate granger causality by use of vector error correction (VEC) specifications. VEC specification only applies to cointegrated series which are non stationary at levels (Granger, 1988); hence the cointegrated vectors presented the necessity to investigate the granger causality between the manufacturing growth and disaggregated energy consumption in Kenya by use of vector error correction approach.

4.4 Tests for granger causality

Testing for causality in the granger sense, commonly involve *F-statistic tests* to determine whether lagged information on independent variables provides any statistically significant information about the dependent variable. Hence, it became imperative to determine the optimal lag lengths of the variables hereunder investigations. To establish the optimal lag length, we adopted the Akaike information criterion (AIC) and the Schwartz information criterion (SIC). The two methods have popularly been used in time series empirical studies and according to Gosh, (2006) the techniques have mostly given successful results. The optimal lag length for all the systems of equations is one lag, which is automatically established at the point where two criteria attain their smallest values: AIC (-10.3) and SIC (-10.0) under E-Views.

Table 4: Lag length selection
Lag Order Selection Criteria

Endogenous variables: DLOG_MNFG_ DLOG_ELC_ DLOG_PET_

Lag Length	AKAIKE I. CRETERION	SCHWARZ I. CRITERION
1	-9.648352*	-9.252472*
2	-9.584298	-8.792538
3	-9.387723	-8.200084

* indicates lag order selected by the criterion
AIC: Akaike information criterion
SC: Schwarz information criterion

In a vector error correction modeling approach, Granger (1988), and Engle and Granger (1987), recommend for an estimation of the residual values of the error correction terms of the series. The objective is to establish their normality and stability to help in estimating the long run equilibrium between the variables. The following table 4 and 6 is the reported results for normality and stationarity of the VEC residuals.

Table 5: Jarque-Bera test for normality of the residuals

Obs	DLOG_MNFG__RESID01	DLOG_ELC__RESID02	DLOG_PET__RESID03
Jarque-Bera	54.40917	12.19952	1.284546
Probability	0.05000	0.322243	0.526095
Observations	38	38	38

The reported probabilities are the probabilities that a Jarque-Bera statistic exceeds (in absolute value) the observed value under the null hypothesis-a large probability value leads to the rejection of the null hypothesis of non-normal distribution. Observably, all the variables were significantly different from zero in their absolute terms. We therefore reject the null hypothesis to accept that all variables are normally distributed at the 5% significance level around their mean. We then proceed to test for the presence of unit roots of the VEC residuals.

Table 6: Error correction unit root tests

Null Hypothesis: Unit root (individual unit root process)

Series: RESID(MNFG), RESID(ELC), RESID(PET)
Sample: 1971 2010
Automatic selection of lags based on SIC: 0-

Intermediate ADF test results LEVEL					Intermediate ADF test results D(LOG)				
Series	Prob.	Lag	Max Lag	Obs	Series	Prob.	Lag	Max Lag	Obs
RESID(MNFG)	0.0002	0	9	37	D(RESID01)	0.0000	1	9	35
RESID(ELC)	0.0000	0	9	37	D(RESID02)	0.0000	1	9	35
RESID(PET)	0.0001	0	9	37	D(RESID03)	0.0000	1	9	36

The ADF unit root diagnostics at Level and the D(LOG shows that their associated *p*-value are less than critical values at 1% and 5% respectively. The statistic values are less than the critical values so then we reject the null hypothesis and accept that the VEC residuals are stationary and therefore able to help in the analysis of granger causality among the series.

Granger Causality in vector error correction model

Kenya has a large manufacturing sector serving both the local market and exports to the East African region. The sector, which is dominated by subsidiaries of multi-national corporations, contributes approximately 13% of the Gross Domestic Product (GDP). The empirical results of the first system of the vector equation:

$$\Delta \ell nMNFG_t = -0.0013 + 0.2591\Delta \ell nMNFG_{t-1} - 0.3376\Delta \ell nELC_{t-1} + 0.0697\Delta \ell nPET_{t-1} - 0.6668ECT$$

$$\text{t-Stat.} \quad [-0.2969] \; [2.5986] \quad [-2.9962] \quad [1.6259] \quad [-5.1810]$$

$$R^2 = 0.5598 \qquad Adj.R-squared = 0.5047 \qquad F-Statistic = 10.1714$$

tested the joint null hypotheses that electricity and petroleum consumption jointly granger causes manufacturing growth in Kenya. A comparison between the empirical (F_E) and critical (F_C) at 0.05 level of significance of the first system equation indicates that $F_E = 10.17$ and $F_C = 2.84$. Therefore, $F_E > F_C \Rightarrow rejectH_0$, we reject the null hypothesis. A rejection of the null hypothesis means that there is granger causality from both electricity and petroleum consumption to manufacturing growth and the error correction model is of a good fit. This is shown by the coefficient of determination (R^2) which in absolute terms represents 56 percent. On the other hand the response rate of manufacturing towards short run shocks of the energy variables is estimated at 66.7%. The granger causality which is unidirectional in nature shows that Kenya's manufacturing sector is energy dependent in both runs. The implication of the above findings will be discussed later in this section.

The second system of equation was to test the joint null hypotheses that manufacturing performance does not granger cause electricity consumption against an alternate hypothesis that manufacturing performance does granger cause electricity consumption in Kenya. From the reported results (table 8) we substitute the model as follows:

$$\Delta \ell nELC_t = -2.9600 + 0.03812\Delta \ell nMNFG_{t-1} - 0.0936\Delta \ell nELC_{t-1} + 0.1312\ell nPET_{t-1} - 0.6450ECT$$

$$\text{t-stat} \quad [-0.0043] \; [0.2353] \quad [-0.5114] \quad [1.8843] \quad [-3.0852]$$

$$R^2 = 0.435 \qquad Adj.R-squared = 0.3644 \qquad F-Statistic = 6.1593$$

We again compare the empirical (F_E) and critical (F_C) at 0.05 level of significance: $F_E = 6.16$ and $F_C = 2.84$. Therefore, $F_E > F_C \Rightarrow rejectH_0$, we reject the null hypothesis. It implies there is unidirectional causality from manufacturing to electricity consumption. The coefficient of the error correction term 0.645 indicates the response rate of manufacturing towards short run shocks of the energy variables. It implies that manufacturing responds at 64.5% towards deviations caused by energy variables in short run periods.

In the third system of equation, the main interest of the study was to test the null hypotheses that manufacturing performance does not granger cause petroleum consumption. The substituted coefficients and diagnostics statistic are as follows:

$$\Delta \ell nPET_t = 0.0057 - 0.1928\Delta \ell nMNFG_{t-1} + 0.2006\Delta \ell nELC_{t-1} - 0.4336\ell nPET_{t-1} - 0.4548ECT$$

$$\text{t-stat} \quad [0.3425] \; [-0.4940] \quad [0.4552] \quad [0.1677] \quad [-0.9033]$$

$$R^2 = 0.1907 \qquad Adj.R-squared = 0.0895 \qquad F-Statistic = 1.8847$$

At 5% level of significance: $F_E = 1.884$ and $F_C = 2.84$. Therefore, $F_E < F_C \Rightarrow acceptH_0$, we accept the null hypothesis which imply that there is no granger causality from manufacturing to petroleum consumption in both short run and the long run period. This is further confirmed by the low standard error of estimates. The above findings are discussed as follows.

Discussions of findings

There is a joint granger causality from electricity and petroleum consumption to manufacturing in short and long run periods, and bidirectional causality between manufacturing and electricity consumption in both runs. The manufacturing sector in Kenya is made up of textiles and garment, cement, iron and steel products, food processing and beverages and wood and paper products which require electricity for smooth operation. The extent that in 2006/2007 the electricity power rationing in the country cost the manufacturing sector a negative growth rate of 2.3% (KIPPRA, 2008) implies that electricity means a lot to this sector. However, the non causality from manufacturing to petroleum consumption can be attributed to the fact that very few manufacturing industries in Kenya significantly depends on oil, which may be qualified to be as a result of high cost and price volatilities. Fossil cost and volatilities of its price impacts directly on prices of manufacture products, thus making Kenya's manufacture less competitive in the regional markets. Consequently most manufacturing firms are migrating to hydro-energy based technologies. Therefore changes in the sector's growth may not significantly change petroleum consumption in Kenya. However, given that there are good indications of petroleum potential within the country, the trend may change in future.

References

Akinlo, A.E. (2008), *Energy Consumption and Economic Growth: Evidence from 11 Sub- Sahara African Countries*. Energy Economics, 30(5), 2391–2400.

Asafu-Adjaye, J. (2000), "The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries", *Energy Economics*, 22: 615-625.

Aqeel, A. and Butt, M. S. (2001) "The relationship between energy consumption and economic growth in Pakistan", *Asia-Pacific Development Journal*, Vol. 8 (2), pp. 101-10.

Costantini, V. and C. Martini (2010). The causality between energy consumption andGDP growth: A multi-sectoral analysis using non-stationary cointegrated panel data. *Energy Economics 32*(3), 591-603.

Ebohon, O. J., (1996) "Energy, GDP growth and Causality in Developing Countries: A Case Study of Tanzania and Nigeria", *Energy Policy,* Vol.24, No.5.

Engle, R.F., Granger, C.W.J. (1987), *Cointegration and Error-Correction: Representation, Estimation and Testing*. Econometrica, 55, 251–276.

Erol, U., Yu, E.S.H., (1987), *On the causal relationship between energy and income for industrialized countries.* Journal of Energy and Development, 13, 113–122.

Esso, L.J., (2010), Threshold cointegration and causality relationship between energy use and growth in seven African countries. Energy Economics 32, 1383-1391.

Ghosh, S. (2006), "Electricity consumption and GDP growth in India", *Energy Policy*, 30, 2032-37

Granger, C. W. J. (1988) "Some recent developments in a concept of causality", *Journal of Econometrics, Vol.* 39. Pp 213-228

Government of Kenya (2010), Economic Survey, Nairobi: Government Printer.

Gujarati ,D.N., S. Sangeetha *(*2007*) Basic Econometrics. Fourth edition*, Published by TATA McGraw-Hill.

Hondroyiannis, G., S. Lolos and E. Papapetrou (2002), "Energy Consumption and GDP growth: Assessing the Evidence from Greece", *Energy Economics*, Vol. 24. Pp 118-132

Jumbe, C. B. L. (2004). "Cointegration and causality between electricity consumption and GDP: empirical evidence from Malawi", *Energy Economics,* Vol. (26), pp. 61- 68.

Kraft, J., Kraft, A., (1978). *On the relationship between energy and GNP*. Journal of Energy and Development, 3, 401–403.

Lee, C. and C. Chang (2008). Energy consumption and GDP growth in Asian economies: A more comprehensive analysis using panel data. *Resource and Energy Economics 30*(1), 50-65.

Odhiambo, N.M., (2010). "Energy consumption, prices and economic growth in three SSA Countries": A comparative study. Energy Policy 38(5), 2463-2469.

Onuonga, S.M. (2012), *The relationship between commercial energy consumption and Gross Domestic Product in Kenya*, The journal of developing areas, Vol. 46, number 1, Spring 2012: 305-314.

Pokharel, S. H., "An Econometrics Analysis of Energy Consumption in Nepal", *Energy Policy,* 2006, pp.1-12.

Sari, R., Ewing, B. T., & Soytas, U. (2008). The relationship between disaggregate Energy consumption and industrial production in the United States: An ARDL approach. *Energy Economics*. Vol 30, Issue 5 (Pages 2302–2313)

Soytas, U., Sari, R. (2007), *The relationship between energy and production: evidence from Turkish manufacturing industry.* Energy Economics, 29(6), 1151–1165.

Sims, C. A. (1972). Money, income, and causality. *American Economic Review 62*(4),540-552.

Stern, D.I. (2000). "A multivariate cointegration analysis of the role of energy in the US macroeconomy", *Energy Economics*, Vol.22, pp.267-83.

Wolde-Rufael, Y. (2006), *Electricity consumption and economic growth: a time series experience for 17 African countries,* Energy Policy, 34, 1106 –1114.