International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2016, 6(2), 195-201.

Electricity Consumption and Manufacturing Sector Productivity in Nigeria: An Autoregressive Distributed Lag-bounds Testing Approach

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ABSTRACT

This paper employs the autoregressive distributed lag technique to provide evidence of long run and short run relationship, as well as the causality between manufacturing productivity and electricity consumption in Nigeria for the period 1980-2013. When electricity consumption, capital formation and manufacturing productivity are applied as the dependent variable(s), the bounds test provides a proof of cointegration among electricity consumption, manufacturing productivity, and capital. Similarly, the findings demonstrated bidirectional causality between manufacturing productivity and energy consumption. Nigeria is along this line an electricity reliant nation. It is likewise a nation in which electricity consumption is rising with the manufacturing productivity. This demonstrates that electricity is a powerful determinant of manufacturing performance in Nigeria; accordingly, policy on energy should guarantee that electricity creates less negative effects on manufacturing productivity.

Keywords: Electricity Consumption, Manufacturing Productivity, Autoregressive Distributed Lag, Nigeria
JEL Classifications: Q430, O470

1. INTRODUCTION

The disagreement on the association connecting energy consumption with gross domestic product (GDP) was adequately investigated in energy economics literature Ocal et al. (2013). Diverse empirical findings were maintained and in many instances found to be contradicting. A lot of factors have contributed to these discrepancies, among which are: Dissimilar variables employed, differences in period of study, disparities in energy consumption of nations investigated and diverse methodology employed.

The causal link among energy consumption and GDP bears crucial policy significance. For this reason, many studies have made effort to establish the link connecting energy consumption to GDP. Taking the instances of Asafu-Adjaye (2000), Soytas and Sari (2003), Wolde-Rufael (2009), Shahbaz et al. (2014), Iyke and Odhiambo (2014) and, Ozturk and Bilgili (2015) among many others, energy consumption and GDP nexus was found to have a conflicting and contradicting findings among scholars. Therefore, the results of the causality tests is justified by a wide range of findings in the literature for most of these studies.

Detailing into energy literature, it is not possible to conclude about the direction of causality among energy consumption and GDP without having a doubt. Acknowledging the fact that this causality is of significance in designing energy policy and implementations, the need to understand the nature of the causality between GDP and energy for better policy making cannot be over emphasized. In a nation where causality keeps moving from GDP to energy consumption (an economy where energy consumption is guided by GDP), the policy of energy preservation will have a small consequence on GDP. On the contrary, in a nation where causality keeps moving from energy consumption to GDP (economy that depend on energy), a watchful energy policy will be recommended given the fact that any negative shock on energy supply will have negative consequence on economic growth (Ouédraogo, 2010).

This study is regarded as a study related to the previous studies concerning the link connecting energy consumption with economic growth. The study will therefore significantly contribute to the field of energy economics as most of the previous studies on energy-economic growth largely focus on total GDP and there is a need to investigate the impact of energy consumption on the manufacturing sector productivity in isolation, as growth in total productivity of the manufacturing sector will lead to increase in economic growth in general. Consequently, This study explore the connection between energy consumption and manufacturing sector productivity in Nigeria for the period 1980-2013.

The remainder of this paper is planned as follows: Section 2 provides concise review of literature relating energy consumption to GDP while methods of data analysis are filled in Section 3. Section 4 presents the empirical estimations of results for the research and lastly, Section 5 discloses the findings and concludes the study.

2. REVIEW OF LITERATURE

The link connecting energy consumption with GDP has been an issue of intense debate in the literature. Economists are still unable to arrive at an agreement on the kind as well as nature of the causal relationship that connect energy consumption with GDP. This was owing to the fact that the causal direction among economic variables and energy consumption, in addition to the techniques utilized to build up this connection remain debatable. For instance, on account of the United States, while Kraft and Kraft (1978) contended that causality keeps running from GNP to energy consumption, a unidirectional causality from energy consumption to employment was discovered in the studies of Akarca and Long (1980). Also, Soytas and Sari (2003) maintains no considerable causal connection among income and energy consumption. Equally important, Lee (2006) suggested bidirectional causality among GDP and energy consumption by utilizing a multivariate framework. In the same way for 11 MENA countries, while Ozturk and Acaravci (2011) believe that electricity consumption and GDP are neutral. Lee (2006) claims that there is evidence for unidirectional causality running from energy to income.

Exploring energy-economic growth relationship in Europe, contradicting findings were established for many European countries. For instance, Hondroyiannis et al. (2002) proved the evidence of a long run relationship as well as feedback causality on energy consumption, price and GDP for Greece by applying error correction model (ECM). Similarly, Soytas and Sari (2003) established the presence of causality moving from energy consumption to economic growth for Germany, Turkey and France and turned around for Italy as causality keeps moving from GDP to energy consumption. Likewise, the findings further disclosed no relationship for the United Kingdom (UK) and Poland. Furthermore, Lee (2006) notes the presence of causality moving from energy consumption to GDP in Netherlands, Belgium and Switzerland; even though different result was found for France and Italy as causality keeps moving from economic growth to energy consumption. The result further demonstrated a bidirectional causality for Sweden as the neutrality hypothesis was maintained for Germany and the UK.

In Latin America, Cheng (1997) demonstrated the evidence of no causality in Mexico and Venezuela, although causality has been confirmed existing from energy consumption to economic growth for Brazil. Similarly, Squalli (2007) discovered a one way causality moving from power to GDP for Venezuela. Within panel context, Apergis and Payne (2009) utilized the panel cointegration as well as ECM in exploring the link connecting energy consumption with GDP for Costa Rica, Nicaragua, Guatemala, El Salvador, Panama and Honduras. The result revealed the existence of cointegration and further discovered both long run and short-run causality running from energy consumption to GDP.

In the case of Asia, Masih and Masih (1996) confirmed no evidence of causality for Malaysia, Singapore and Philippines while causality was found running from energy consumption to economic growth for India. Although causality keeps moving from economic growth to energy consumption in Indonesia, a feedback relationship was declared for Pakistan. In the same way, Cheng and Lai (1997) investigates the case of Taiwan using the Granger causality approach and revealed a unidirectional causality from economic growth to energy use. Utilizing cointegration and ECM in the case of four Asian countries, Asafu-Adjaye (2000) established an evidence of a one way causality moving from energy to income for Indonesia and India, as well as feedback causality for Thailand and Philippines. Likewise, Soytas and Sari (2003) maintained causality from economic growth to energy use for Korea as well as from energy use to economic growth in Japan. Contrary evidence of neutrality hypothesis was established for India and Indonesia. Furthermore, Ozturk and Salah Uddin (2012) revealed a feedback causal relationship between energy and GDP for India. Finally, Yildirim et al. (2014) study energy-growth nexus for Asia and maintained neutrality hypothesis for Singapore.

In the African nations, Ebohon (1996) explained a feedback relationship among energy consumption and GDP for Tanzania and Nigeria. In another study, Jumbe (2004) discovered similar feedback association for electricity consumption and GDP in Malawi using cointegration and ECM. Employing autoregressive distributed lag (ARDL) Bound test and Toda–Yamamoto statistical inference for 19 countries in Africa, Wolde-Rufael (2005) claimed the proof of causality moving from GDP to energy use in Ghana, Egypt, Ivory Coast, Algeria and Congo Republic. The findings further suggested causality moving from energy consumption to GDP in Cameroon along with a negative causality from energy to GDP for Nigeria and Morocco. In the same way, bidirectional causal relationship was recognized for Zambia and Gabon as evidence of no causality was revealed for Zimbabwe, Benin, Togo, Senegal, Congo Republic, Sudan, South Africa, Tunisia and Kenya.

From the above literature, It can be deduce that there are contradicting findings on either the existence or the direction of causality between energy consumption and economic growth. Hence, this study reinvestigates the relationship between electricity consumption and manufacturing productivity with the aim of filling this gap in the literature.

3. METHOD OF DATA ANALYSIS

3.1. Unit Root Test

The prerequisite condition in the time series analysis recommends series to be stationary. Non-stationary of time series data in most cases are considered as issue in an empirical analysis as the use of non-stationary series can bring about spurious regression. Therefore, the importance of unit root test cannot be over emphasized in determining whether the variables are stationary or not. This study therefore utilized the augmented Dickey and Fuller (1979) as well as the Phillips and Perron (1988) unit root tests for its analysis. The augmented Dickey-Fuller (ADF) consists of estimating the following equations:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^{\rho} \alpha_1 \Delta Y_{t-1} + \varepsilon_t \qquad (1)$$

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + \sum_{i=1}^{\rho} \alpha_1 \Delta Y_{t-1} + \varepsilon_t \qquad (2)$$

$$\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^{\rho} \alpha_1 \Delta Y_{t-1} + \varepsilon_t \qquad (3)$$

Where:

ε_t is the white noise, β_1 represent the intercept and $\Delta Y_t = (Y_t - Y_{t-1}), \Delta Y_{t-1} = (Y_{t-1} - Y_{t-2}),\ i=1, 2,3\ldots\ldots N.$

As in the ADF test, the Phillips–Perron (PP) test was also built on the first order autoregressive of the ADF. The major difference was that the PP test administered a non-parametric correction on the t-statistics of the attribute of the first order autoregressive process to take care of serial correlation in the error term.

3.2. Cointegration Test

Following the unit root test, the next process is to estimate the long run cointegration among energy consumption and manufacturing performance using the ARDL-bounds testing procedure. The ARDL model begins with the work of Pesaran et al. (1999) which was later extended by Pesaran et al. (2001). The ARDL-bounds testing approach to cointegration has a number of advantages when compared to other cointegration approach. Firstly, the ARDL approach can be applied whether the variables are I(0) or I(1). Thus, this approach stay away from the pre-testing problems related with the other cointegration approach which required all the variables to be stationary at level or all at first difference. Besides, the ARDL approach is significant in determining cointegration even when the size of the sample is small, whereas other techniques of cointegration respond to sample size. Moreover, this approach has less problem of endogeneity because it is free of residual correlation (Harris and Sollis, 2003). The ARDL model employed in this study is given as follows:

$$\Delta manf_t = \alpha_o + \sum_{i=1}^{n} \alpha_{1i} \Delta manf_{t-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta elect_{t-i} + \sum_{i=0}^{n} \alpha_{3i} \Delta cap_{t-i} + \sum_{t=0}^{n} \alpha_{4i} \Delta lab_{t-i} + \alpha_5 manf_{t-i} + \alpha_6 elect_{t-i} + \alpha_7 cap_{t-i} + \alpha_8 lab_{t-i} + \varepsilon_t \qquad (4)$$

Where:

Elect is the electricity consumption kWh per capita
Manf is the manufacturing productivity (measured by manufacturing value added)
Lab is the labor measure by labor force participation rate % of total population 15-64 years
Cap Represents capital measured by gross capital formation
t Represents the time period
Δ Represents the first difference operator
ε_t Represents the error term
$\beta, \rho, \alpha, \gamma$ are parameters of the model.

The bounds test procedure is based on F-statistic for cointegration analysis. The null hypothesis of no cointegration among the variables in Equation (4) is given by H_0: $\alpha_5 = \alpha_6 = \alpha_7 = \alpha_8 = 0$ as against the alternative hypothesis H_1: $\alpha_5 \neq \alpha_6 \neq \alpha_7 \neq \alpha_8 \neq 0$. If the calculated statistic test is greater than the upper critical bounds value, then the H_0 will be rejected and conclude that there is cointegration. On the contrary, if the F-statistic falls within the bounds, then the cointegration test becomes inconclusive. If the F-statistic is lower than the lower bounds value, then we fail to reject the null hypothesis of no cointegration.

In order to select the optimal model, the ARDL method estimate $(p+1)^k$ number of regressions, where *k,* represents the number of variables while *p,* represents the maximum number of lags. The optimal model is selected based on the Akaike information criteria (AIC). The ARDL long run model (p_1, q_1, q_2, q_3) specification model is given by:

$$manf_t = \beta_0 + \sum_{i=1}^{p_1} \beta_{1i} manf_{t-i} + \sum_{i=0}^{q_1} \beta_{2i} elect_{t-i} + \sum_{i=0}^{q_2} \beta_{3i} cap_{t-i} + \sum_{i=0}^{q_3} \beta_{4i} lab_{t-i} + \mu_t \qquad (5)$$

After the long-run relationships are ascertained, third step is to investigate the short-run model through ECM using Equation (6).

$$\Delta manf_t = \phi_o + \sum_{i=1}^{n} \phi_{1i} \Delta manf_{t-i} + \sum_{i=0}^{n} \phi_{2i} \Delta eng_{t-i} + \sum_{i=0}^{n} \phi_{3i} \Delta cap_{t-i} + \sum_{t=0}^{n} \phi_{4i} \Delta lab_{t-i} + \phi_5 ECT_{t-i} + \mu_t \qquad (6)$$

Where ECT_{t-1} represents the error-correction term; and μ_t is the error term. The estimated results of the *ECM* measure the speed of adjustment needed to converge back to long run equilibrium after a short-term shock.

To make sure that the model is suitable, the study is exposed to stability and diagnostic tests. These include: The test for stability, normality, serial correlation as well as heteroscidasticity related with the model. For the stability test, the study employed the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) using Brown et al. (1975) stability test as proposed by Pesaran and Pesaran (1997). If the CUSUM and CUSUMSQ plotted is within the critical bonds at 5% level of significance, the null hypothesis of the regression coefficients are stable and hence cannot be rejected.

4. ESTIMATIONS RESULTS

4.1. Unit Root Test

The fact that the Bounds test do not necessarily need the entire variables to be I(0) or I(1), it is essential to estimate the stationarity properties of the data so as to make sure that the variables are not integrated at I(2). This is owing to the fact that the F-test would be spurious if exist I(2) variables. This is because both the critical values of the F-statistics estimated by Pesaran et al. (2001) and Narayan and Smyth (2005) depend on the presumption that the variables are I(0) or I(1).

The unit root test for stationarity in Table 1 was based on the ADF and PP tests. The results reported disclosed that capital and labour are stationary at level using both the ADF and PP test, whereas, manufacturing productivity and electricity consumption become stationary after differencing. The ADF and PP tests applied to the level data fail to reject the null hypothesis of non-stationarity for manufacturing productivity and electricity consumption until it is applied at the first difference. Hence, reject the null hypothesis of non-stationarity for manufacturing productivity and electricity consumption. It is, therefore, concluded that capital and labour are I(0) variables whereas manufacturing productivity and electricity consumption are I(1) variables. This justifies the necessity of employing ARDL approach to cointegration.

4.2. Cointegration Test

This sub-section demonstrates the long-run cointegration among (*Manf, Elect, Cap and Lab*) using the ARDL bounds testing technique. Firstly, The lags order of the variables in Equation (4) are ascertained from the unrestricted models using AIC for the Model. Following the establishment of the optimal lag length, the next stage is to administer the bounds F-test on Equation (1) to determine the long-run association among the variables under study. The results of the bounds test are Shown in Table 2.

The results for the F-statistics presented in Table 2 display that when manufacturing productivity *(Manf)* is utilized as the dependent variable, the calculated F-statistic is higher than the critical value at 5% level of significance. Moreover, utilizing electricity consumption *(Elect)* as the dependent variable, the calculated F-statistics is higher than the critical value at 5% level of significance. Similarly, employing capital *(Cap)* as the dependent variable, the calculated F-statistics is also higher than the critical value at 5% level of significance. On the contrary, when labour *(Lab)* is used as the dependent variable, the calculated F-statistics is lower than the lower-bound critical values at 10% level of significance. In general, this indicates that there is cointegrating relationships among the variables in the models.

4.3. Long Run Estimation Result

Having established long run relationships among manufacturing productivity, electricity consumption, capital and labour, next is to estimates the coefficient of the long run among the variables. The long run ARDL coefficients point out the nature of the relationship among manufacturing productivity and the possible regressors utilized in the model. The results of the long run coefficients are shown in Table 3. The result of the long run portrays a positive relationship among manufacturing productivity and electricity consumption as well as capital input. The result demonstrates that any 1% increase in electricity consumption and capital input will respectively, result in 0.58% and 0.39% increase in the manufacturing productivity. By implication, the long run coefficients shows that electricity consumption and capital are the key determinants of manufacturing productivity. This is in line with the study of Sari et al. (2008) for US; Odhiambo (2009) for Tanzania; and, Ozturk and Acaravci (2010) for Albania, Bulgaria, Hungary and Romania.

Table 1: Unit root test

Series	ADF		PP	
	Level	First difference	Level	First difference
Manf	3.514	−5.494*	−5.536	−5.674*
	(1.000)	(0.000)	(1.000)	(0.000)
Elect	4.418	−6.527*	0.171	−8.593*
	(1.000)	(0.000)	(0.996)	(0.000)
Cap	−4.270*	−6.848*	−4987*	−6.266*
	(0.009)	(0.000)	(0.007)	(0.000)
Lab	−5.461*	−2.614*	−2.7**	−2.040*
	(0.000)	(0.011)	(0.078)	(0.041)

The figures in parenthesis indicate the probability of the t-statistic. *and** represent 5% and 10% respectively. ADF: Augmented Dickey-Fuller, PP: Phillips–Perron

Table 2: Test for cointegration and critical bounds of F-statistics

	1%		5%		10%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
	4.3	**5.23**	**3.38**	**4.23**	**2.97**	**3.74**
Calculated F-statistics						
Manf	5.999*	-	-	-	-	-
Elect	9.433*	-	-	-	-	-
Cap	8.985*	-	-	-	-	-
Lab	1.642	-	-	-	-	-

*Represents 5% significance

4.4. Short Run Estimation Result

Having established long run relationships among manufacturing productivity, electricity consumption, capital and labour, and the long run coefficients, next is to estimates the coefficient of the short run among the variables. The results of the short run ECM are presented in Table 4.

The short run relationship between manufacturing productivity, electricity consumption, capital and labour is examined in Table 4 through the use of the *ECM*. The error correction term (*ECT)* represents the extent of the deviations of the explanatory variables away from the long run alignment. The size of the *ECT* coefficient −0.49 indicates about 49% speed of adjustment towards the long run equilibrium within a year. The result was in consistent with the study of Sari et al. (2008) for the US. Also in the short run, both electricity consumption and capital inputs are positively related to manufacturing productivity. During the short run, 1% rise in electricity consumption and capital will increase manufacturing productivity by 0.31% and 0.20%, respectively.

Table 3: Long run coefficient

Dependent variable: Manufacturing productivity, ARDL (2, 2, 2, 1)				
Regressors	Coefficients	Standard error	t-statistic	Probability
Estimated long run coefficient				
Elect	0.5775	0.1492	3.8706	0.001*
Cap	0.3941	0.0561	7.0249	0.000*
Lab	0.4722	1.6495	0.2862	0.777
Intercept	0.0144	0.0018	7.8823	0.000*

*Represents 5% significance. ARDL: Autoregressive distributed lag

Table 4: Short run ECM

Dependent variable: Manufacturing productivity, ARDL (2, 2, 2, 1)				
Regressors	Coefficients	Standard error	t-statistic	Probability
C	7.1225	1.1846	6.0041	0.0000*
$\Delta LMANF(-1)$	0.4974	0.1715	2.9002	0.0089*
$\Delta LELECT$	0.3094	0.1081	2.8621	0.0096*
$\Delta LELECT(-1)$	−0.509	0.1008	−5.0496	0.0000*
$\Delta LCAP$	0.2011	0.0628	3.2022	0.0045*
$\Delta LCAP(-1)$	−0.1601	0.0559	−2.864	0.0097*
ΔLAB	7.1882	3.4569	2.0793	0.0507*
$ECT(-1)$	−0.4923	0.1449	−3.3975	0.0000*

*Represents 5% significance, ECM: Error correction model, ARDL: Autoregressive distributed lag, ECT: Error correction term

4.5. Causality Test Result

Having establish the long-run and the short run relationship among manufacturing productivity *(Manf)* and electricity consumption *(Elect)*, next is to estimate the causality between the variables. The results of the causality tests are reported in Table 5.

Table 5 presents the causal relationship between electricity consumption and manufacturing productivity. The result established a positive causality running from electricity consumption to manufacturing productivity as well as evidence that support the manufacturing productivity-led hypothesis. Thus, there exist a bidirectional relationship between manufacturing productivity and electricity consumption. The findings are in line with the studies of Ozturk and Acaravci (2010) for Albania, Bulgaria, Hungary and Romania; Fuinhas and Marques (2012) for Portugal, Italy, Greece, Spain and Turkey. This implies that electricity consumption and manufacturing productivity are complementing each other. Meaning that, electricity consumption operates as a stimulant to manufacturing productivity, also a high manufacturing productivity requires more electricity consumption. This finding indicates that in Nigeria, policies on energy should be directed towards improving electricity infrastructure that will increase the supply of electricity. Electricity preservation policies may hinder manufacturing productivity and economic growth in general.

4.6. Diagnostic Checking

To make sure that the stated results are free from spurious inference, the competency of the model specified is further verified through diagnostic tests. The result in Table 6 pointed out that the null hypothesis of no serial correlation, homoskedasticity as well as the normality of the distribution of the residuals were not rejected. Hence, it is concluded that the model has pass the diagnostic test.

Table 5: Granger causality test result

Null hypothesis	F-statistics	Probability
Elect does not Granger cause *Manf*	9.8287	0.0000*
Manf does not Granger cause *Elect*	14.3638	0.0000*
Cap does not Granger cause *Manf*	0.1479	0.3323
Manf does not Granger cause *Cap*	3.4001	0.0482*
Lab does not Granger cause *Manf*	1.2154	0.3123
Manf does not Granger cause *Lab*	0.7299	0.4912

*Represent significance at 5%

Table 6: Diagnostic test of the ARDL model

Test statistics	F-statistics	Probability
Autocorrelation	0.18	0.7296
Normality	0.562	0.7548
Heteroskedasticity	1.237	0.2601

ARDL: Autoregressive distributed lag

The strength of the results can be additionally established by means of the cumulative sum of recursive residuals (CUSUM) and cumulative sum of recursive residuals square (CUSUMQ). Moreover, the plots exposed that the series are within the critical bound at 5% level of significant. This therefore, proves the stability of the model over time. The CUSUM and CUSUMQ are graphically presented in Figures 1 and 2, respectively.

5. POLICY IMPLICATION

From policy perspective, the findings emphasized the importance of policy on energy in general and electricity in particular, on manufacturing productivity. This is because electricity consumption and manufacturing productivity complement each other. Considering the fact that electricity stimulates manufacturing productivity, also a high manufacturing productivity requires more electricity. Therefore, there is the need to implement policies that will enhance electricity supply, for example, the amendment of the electricity and NEPA acts 1998 to remove monopoly and encourage private sector participation will increase electricity supply and further enhance electricity consumption. Consequently, policy on energy and the restructuring of electricity sector should meet up with the designed goal of enhancing energy consumption. Policy makers should therefore implement policies such that electricity should not be a barrier to manufacturing performance. The energy preservation policy can have an adverse effect on manufacturing productivity in particular and economic growth in general in consideration of companies heavily relying on electricity.

6. CONCLUSION

This study investigates the long run, short run and the causal relationship between manufacturing productivity and electricity consumption in Nigeria. The bounds testing technique reveals the existence of cointegration between manufacturing productivity and electricity consumption. It further proves a bidirectional relationship between manufacturing productivity and electricity consumption. While the finding confirms that Nigeria relies on electricity; it equally reveals that electricity consumption increases

Figure 1: CUSUM stability test

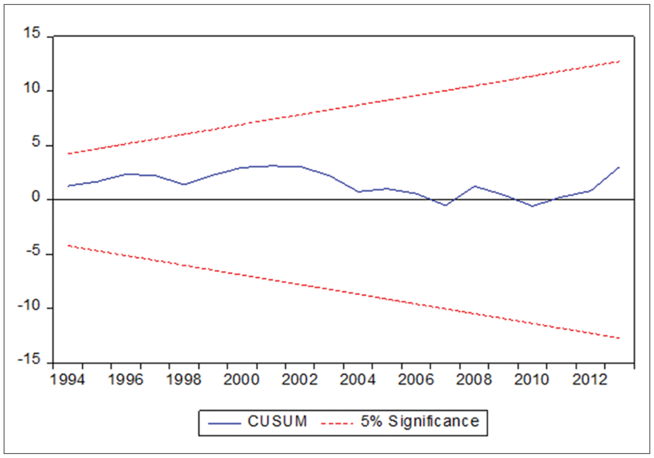
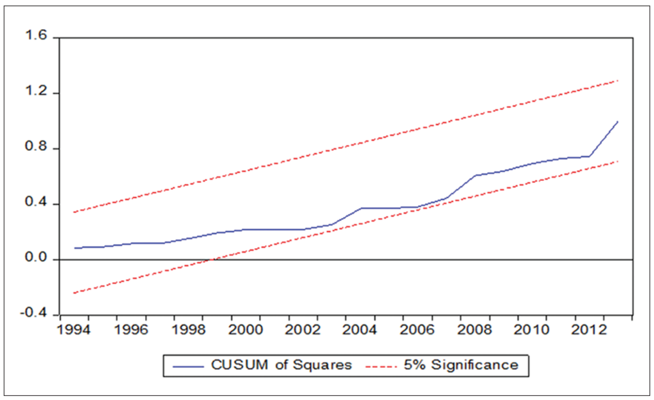


Figure 2: CUSUMQ stability test



with manufacturing productivity. Therefore, policy on energy should guarantee that electricity creates less negative effects on manufacturing performance.

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