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# Energy Consumption-Economic Growth Nexus: Evidence from Linear and Nonlinear Models in Selected African Countries

**Ibrahim D. Raheem[1], Agboola H. Yusuf[2]**

[1]Centre for Petroleum, Energy Economics and Law, University of Ibadan, Nigeria. Tel.: +234-703-2659866. Email: i_raheem@ymail.com,
[2]Department of Economics, University of Ilorin, Nigeria. Tel.: +234-803-7289712. Email: agboolayusuf2009@yahoo.com

**ABSTRACT**

In the energy-growth nexus, due to structural change that cannot be accounted for in the linear model this study considers the possibility of the nonlinear model. Using dataset for fifteen countries in Africa for the period 1980-2010, we found that linear model has misspecification error, thus, lending support for the nonlinear model. We provide evidence of inverted "U" shape in Benin, Cote d'Ivoire, Egypt, Togo and Tunisia. This also confirms Environmental Kuznet Curve hypothesis. The low regime of energy consumption (EC) retards growth in Sudan and South Africa, while high regime of EC enhances growth in Algeria, Morocco and Senegal. We also find evidence of neutrality hypothesis in Cameroon and Zambia.

**Keywords:** Energy consumption, Economic Growth, Threshold Regression Model, Africa
**JEL Classifications:** C22, O40, Q53, Q56

## 1. INTRODUCTION

The importance of energy in enhancing economic growth and development of an economy cannot be overemphasized. All the activities within an economy in terms of production, distribution and consumption of goods and services require energy as its input. Thus, energy is regarded as a key driver of economic growth and industrialization (Esso, 2010; Mensah, 2014). Due to this perceived importance of energy in an economy, several studies have been conducted to understand the linkage(s) between and/or among energy consumption (EC) and macroeconomic variables (in most cases economic growth). The seminar paper of Kraft and Kraft (1978) laid the foundation on the EC-economic growth debate. Subsequent studies have tried to model this relationship using different methodologies, scopes, and model specifications. This might account for the reason why the debate is inconclusive, among other reasons. The EC-growth linkage can be decomposed into four hypothesizes: the "neutrality effect" - a situation in which there is no causation in the nexus. The "growth effect" relates to the causation running from EC to growth. The "conservative effect" explains the causation running from growth to energy demand. In this case, economic growth cannot be achieved without leading to environmental degradation. Lastly, the "feedback effect" shows the bidirectional causation in the EC-growth nexus. In this case, EC and growth are jointly determined and affect each other at the same time.

Studies in the literature have the following trend: validation of Environmental Kuznet Curve (EKC) hypothesis; causal relationship between EC and growth; expanding the model to account for carbon dioxide ($CO_2$) emission[1]; estimating the coefficients of the EC, $CO_2$ emission and growth nexus. It should be noted that a large proportion of existing studies have focused on testing the causation between energy related issues and growth (Payne, 2010; Omri, 2014 for an extensive literature survey). Econometric techniques of existing studies assume linearity among the variables used in the model(s). However, economic events (e.g. economic crisis, structural adjustment reforms etc.), heterogeneity in (climatic conditions, varying EC pattern and

1 There is a direct relationship between emission and energy consumption. The burning of fossil fuel would lead to emitting $CO_2$ into the atmosphere, which thus, leads to environmental degradation. Since the to energy consumption-growth linkage has been theoretically established, $CO_2$ can be said to be related growth, thus, expanding the linkage to trilogy. Similarly, Saboori and Sulaiman (2013) opined that energy consumption is an important determinant of $CO_2$ emission.

structure and stages of economic development within a country) and changes in regime shift (such as changes in economic environment and energy policy as well as fluctuation in energy prices) cannot be captured by linear models/techniques (Ocal, 2000; Lee and Chang, 2005; 2007; Chiou-Wei et al., 2008; Esso, 2010; Mensah, 2014).

In an attempt to address the problem of nonlinearity raised above, recent studies have been adopting nonlinear models to capture asymmetry in macroeconomics. Among the techniques that have been used include nonlinear Granger causality test to account for structural break(s); threshold cointegration test and threshold auto regressive (TAR) model, which was developed by Tong (1983) and later expanded by Hansen (1996).

Based on the foregoing, the aim of this present study is to provide empirical evidence from both linear and nonlinear models on the relationship between EC and economic growth. In essence, the study conducts time series (TS) analysis for fifteen African countries for the periods 1980-2010[2]. The choice of a TS analysis is based on three reasons. First, TS can keep track of national characteristics and lead to more accurate inferences. Second, differences among countries in terms of economic structure, energy sources and environmental condition may resort to different policy instruments and options. Third, TS provides more insight into important details that are hidden and also averaged-out results such as panel and cross-sectional analysis. Data series are collected from World Development Indicator databank.

The rest of the paper is structured as follows: Section 2 presents brief literature review. Section 3 deals with theoretical framework in which the effect of EC on growth is examined. Empirical results on both linear and nonlinear specifications are reported in section 4. Section 5 concludes the study.

## 2. LITERATURE REVIEW

This section divides existing literature on EC and growth into two major strands. The first strand reviews studies that specified a linear model analysis, while the second strand sheds light on nonlinear model studies. It should be noted that plethora of literature exist for developing countries, while studies on developed countries are rather scanty. Studies that adopt TS analysis focus majorly on developing countries, for instance, China, Turkey, Taiwan, India, and Malaysia have been enormously studied by academics and policy makers. Brazil, South Africa and Indonesia are not left behind[3]. Different estimation techniques for different time periods for a wide range of countries and regions based on series of variables and different data measurements have been used by different studies. Yet, the debate on EC and economic output remains inconclusive among other reasons.

Starting with the first strand, majority of the existing studies have focused on the bivariate relationship between EC and growth. For instance, Kraft and Kraft (1978) in USA, Soytas and Sari (2003) in Italy and Korea; Lee (2006) in France, Italy and Japan, Al-Iriani (2006) in six West Asian countries, Mehrara (2007) in 11 oil exporting countries, Lise and Van Montfort (2007), Ang (2008) in Malaysia, Ozturk et al., (2010) in low income countries and Zhang and Xu, (2012) in China, confirm conservation hypothesis. Under this hypothesis, economic growth can be achieved without necessarily reducing energy demand, which invariably improves environmental quality.

Among the studies confirming growth hypothesis include Stern (1993) in USA, Masih and Masih (1996) in India, Yemane (2004) in China, Lee (2005) for 18 developing countries, Yuan et al. (2008) for China, Ang (2007) in France, Narayan and Smyth (2008) for G-7 countries, Bowden and Payne (2009) in the United States, Apergis and Payne (2009a) in Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama and Tsani (2010) for Greece. In this hypothesis, economic growth is conditioned on increasing energy demand.

Neutrality hypothesis, which implies no causation between energy demand and economic growth have been proved by Glasure and Lee (1998) and Chiou-Wei et al. (2008) in South Korea, Lee (2006) in Germany, Huang et al. (2008) in low income countries; Balcilar et al. (2010) in G-7 countries; Acaravci and Ozturk (2010) in Albania, Bulgaria, and Romania and Fallahi (2011) in USA.

Similarly, feedback hypothesis, which postulate a bidirectional causation between energy demand and economic growth have been confirmed by the studies of Hwang and Gum (1992) and Yang (2000) for Taiwan, Glasure (2002) and Oh and Lee (2004) for Korea, Hondroyiannis et al. (2002) for Greece, Apergis and Payne (2009b) for Commonwealth of Independent States, Lee and Chang (2007) and Mahadevan and Adjaye (2007) for developed countries, and Belloumi (2009) in Tunisia.

Studies on the tri-variate relationship among EC, $CO_2$ emission and economic growth include Ang (2007) for France, Soytas et al. (2007) for United States, Apergis and Payne (2009c) for six Central American countries; Halicioglu (2009), Soytas and Sari (2009) and Ozturk and Acaravci (2010) in Turkey, Chang (2010) for China and Arouri et al. (2012) for 12 MENA countries.

Finally, in somewhat different from the studies stated above and taking into consideration the nonlinear peculiarities in countries as a result of structural policy reforms, economic events in terms of financial crisis, Lee and Chang (2005) accounts for structural breaks in the EC-growth nexus in Taiwan. In a similar spirit, Lee and Chang (2007) developed both linear and nonlinear model for Taiwan. Chiou-Wei et al. (2008) analysed both linear and nonlinear Granger Causality Test as well as BDS test for nine developing and developed economies. Esso (2010) and Mensah (2014) used threshold cointegration for seven African countries and Ghana respectively.

2 The countries captured are Algeria, Benin, Botswana, Cameroon, Cote d'Ivoire, Egypt, Gabon, Kenya, Morocco, Senegal, South Africa, Sudan, Togo, Tunisia and Zambia. Data availability dictated the scope under review.

3 Even though, empirical studies have been bias against Africa, among the notable studies in Africa include Keho (2007), Akinlo (2008 and 2009), Wolde-Rufael (2009), Odhiambo (2009), Esso (2010), Ouedraogo (2013) and Mensah (2014).

## 3. THEORETICAL FRAMEWORK

This section provides theoretical underpinning for both linear and nonlinear model, which draws its insight from Lee and Chang (2007).

It is assumed that the three factors of production are capital stock, labor services and productive energy (which in this case is EC). The model is based on the conventional neoclassical one-sector aggregate production function. Thus the production function is specified as:

$$Y_t = F\left(L_t, K_t, A_t\right) = L_t^{\propto 1} K_t^{\propto 2} A_t^{\propto 3}, \propto 1, \propto 2, \propto 3 > 0 \quad (1)$$

Where $Y$ is real output, $L$ is the total labor force while $A$ measures technological progress, which is proxied by export sector and EC. Hence, the growth rate of output is given by:

$$GY_t = \beta_0 + \beta_1 GL_t + \beta_2 GK_t + \beta_3 GX_t + \beta_4 GEC_t + \varepsilon_t \quad (2)$$

Where GY is the growth rate of real output (gross domestic product [GDP]), GL is the rate of labor force, GK measures the growth of real capital stock, GX is the growth rate recorded in the export sector, GEC is the growth rate of energy use per capital and of course, ε is the error term[4].

In an attempt to examine the non-linear relationship in the energy-growth linkage, the study adopts TAR model. Among the advantages of TAR are that it allows for regime shift in the model specified. It also helps to incorporate the debates in the literature as regards the positive and negative effects of EC on growth. Hence, the model is specified as:

$$GY_t = \beta_0^j + \beta_1^j GK_t + \beta_2^j GL_t + \beta_3^j GX_t + \beta_4^j GEC_t + \varepsilon_t \quad (3)$$

The study makes the assumption that the EC is the variable that will act as regime shift variable, hence, it is the threshold variable, which can be specified as:

$$j = \begin{cases} 1, & if \quad EC_t \le \gamma \\ 2, & if \quad EC_t > \gamma \end{cases} \quad (4)$$

Eq. (3) can be re-specified as follows:

$$GY_t^j = \beta_0^j + \beta_1^j GK_t + \beta_2^j GL_t + \beta_3^j GX_t + \beta_4^j \left[D\left(GEC_t \le \gamma\right)\right] + \beta_5^j \left[D\left(GEC_t > \gamma\right)\right] + \varepsilon_t \quad (5)$$

Where D = dummy variable, which takes the value of 1 if $GEC_t > \gamma$ and 0 if otherwise.

The existence of threshold relationship in the EC-growth nexus is estimated using the procedure proposed by Hansen (1999), which involves estimating Eq. (5) by OLS and computing the Residual Sum of Squares (RSS) for the different chosen threshold level of GC. The threshold of EC is found by selecting the parameter that minimizes RSS, thus maximizing $R^2$.

The next procedure is to test the level of significance using bootstrap method to stimulate the asymptotic distribution of the following likelihood ratio test of $H_0$: $\beta_1=\beta_2$, given as:

$$LR_1 = \left(\frac{S_0 - S_{1K^*}}{\sigma_{K^*}^2}\right) \quad (6)$$

Where $S_0$ is the RSS under $H_0$; $S_{1K*}$ is the RSS under $H_1$;$\sigma^2$ is the residual variance, which can also be expressed as $\frac{1}{T}\left(S_{1K^*}\right)$ and T is the sample size. To determine the critical value, the study uses the confidence interval given as:

$$C\left(\alpha\right) = -2\ln(1-\sqrt{1-\alpha}) \quad (7)$$

Where α is the critical level of significance. The "no rejection region" of confidence level 1-α is a set of values for K, such that $LR_{K*} \le \alpha$. It should also be noted that $LR_{K*}$ is the computed likelihood ratio under H1, $C(\alpha)$ is the constructed asymptotic confidence interval and K* is the threshold level of GC. Thus, if $LR_K > C(\alpha)$, we reject $H_0$ and conclude that the threshold is statistically significant.

## 4. EMPIRICAL RESULTS

This section presents the results of the specifications discussed in the previous section. The econometric analysis of this study is composed of three stages. First, we examined the linear model of the relationship between EC and economic growth. Next, we made an assumption about nonlinearity in the model specified and thus, obtain a threshold value for EC. Lastly, based on the obtained threshold value for EC, the dataset is divided into two sub divisions (below and above the threshold value for EC) to examine their effect individually on growth.

Descriptive statistics are shown in Table 1. Using ordinary least squares approach, Table 2 highlights the estimate parameters of equation (2). The positive relationship in the EC-growth nexus is evident in seven countries (Algeria, Botswana, Cameroon, Morocco, Senegal, Togo and Zambia), though, insignificant with the exception of Zambia. This is suggestive of the fact that EC is not really a strong determinant of economic growth in Africa, which supports "neutrality hypothesis". The importance of capital in enhancing economic growth of African countries has been established in the obtained results. The exact effect of labour is mixed. Export-led growth hypothesis was equally obtained in all the results with the exclusion of Cote d'Ivoire. Across all regressions, absence of serial correlation was established since the values of Dubin Watson test is >1.5. Also, our results do not suffer from spurious regression, as the $R^2$ is lesser than the Dubin Watson statistics.

Turning to the nonlinear model, whose results are presented in Table 3, the threshold value of EC for the individual countries

4 Though, Lee and Chang (2007) expanded the model to account for a two sector-model, however, this study limits its analysis to the one sector model, which is due to lack of data availability.

**Table 1: Descriptive statistics**

| Country | GDP | | | | Capital | | | | Labour | | | | Export | | | | EC | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Mean | Standard deviation | Maximum | Minimum | Mean | Standard deviation | Maximum | Minimum | Mean | Standard deviation | Maximum | Minimum | Mean | Standard deviation | Maximum | Minimum | Mean | Standard deviation |
| Algeria | 27.4 | −11.3 | 3.7 | 5.25 | 37.8 | −20.0 | 6.16 | 12.4 | 5.21 | 2.54 | 0.67 | 18.71 | 38.5 | −25.9 | 2.59 | 8.56 | 25.9 | −5.62 | 1.599 | 17.7 |
| Benin | 9.95 | −4.89 | 3.55 | 3.08 | 96.62 | −41.4 | 10.78 | 27.54 | 4.14 | 2.13 | −0.28 | 18.52 | 37.20 | −27.4 | 3.73 | 13.86 | 14.42 | −16.2 | −2.19 | 16.29 |
| Botswana | 26.36 | −4.93 | 9.21 | 6.28 | 106.9 | −31.2 | 9.31 | 29.08 | 4.43 | 2.33 | −0.06 | 18.56 | 35.01 | −27.9 | 9.98 | 12.97 | 14.09 | −6.90 | −1.57 | 16.28 |
| Cameroon | 22.00 | −7.82 | 3.75 | 5.94 | 47.85 | −27.6 | 5.37 | 16.10 | 3.52 | 1.86 | −0.57 | 18.48 | 44.27 | −16.5 | 4.89 | 13.95 | 5.82 | −7.62 | 2.56 | 15.75 |
| Cote d'Ivoire | 12.91 | −10.9 | 2.63 | 4.53 | 80.97 | −51.5 | 3.86 | 23.19 | 4.63 | 1.56 | −0.42 | 19.85 | 60.78 | −10.6 | 4.72 | 19.84 | 39.20 | −6.79 | 0.77 | 7.67 |
| Egypt | 14.62 | 0.71 | 5.34 | 2.85 | 56.42 | −20.3 | 6.76 | 15.15 | 4.29 | 1.68 | 2.25 | 0.74 | 28.76 | −14.5 | 7.35 | 10.21 | 13.82 | −8.73 | 3.71 | 4.68 |
| Gabon | 39.49 | −24.1 | 3.96 | 10.88 | 180.9 | −61.9 | 9.08 | 38.17 | 3.55 | 1.85 | 2.77 | 0.70 | 50.23 | −17.8 | 3.59 | 12.92 | 34.24 | −19.6 | −0.81 | 9.00 |
| Kenya | 22.17 | −4.65 | 4.34 | 4.46 | 37.75 | −31.5 | 5.05 | 16.20 | 4.26 | 2.72 | 3.48 | 0.79 | 31.52 | −11.6 | 3.50 | 8.37 | 4.93 | −1.96 | 0.006 | 1.44 |
| Morocco | 12.22 | −6.58 | 4.18 | 4.21 | 41.77 | −31.3 | 5.84 | 13.16 | 4.63 | −1.18 | 2.39 | 7.46 | 21.63 | −16.7 | 5.99 | 7.45 | 9.80 | −2.85 | 2.91 | 3.42 |
| Senegal | 8.92 | −5.58 | 3.05 | 3.67 | 47.99 | −40.8 | 6.78 | 20.51 | 3.41 | 1.99 | 2.93 | 0.65 | 48.65 | −34.2 | 3.27 | 14.02 | 5.28 | −7.73 | −0.43 | 3.05 |
| South Africa | 6.62 | −2.13 | 2.63 | 2.37 | 32.85 | −23.3 | 3.41 | 11.99 | 4.20 | 0.96 | 3.12 | 0.97 | 16.45 | −19.5 | 2.60 | 5.86 | 7.86 | −7.65 | 1.02 | 3.82 |
| Sudan | 16.66 | −6.28 | 4.71 | 5.69 | 127.1 | −38.4 | 10.08 | 26.94 | 4.38 | 1.04 | 2.43 | 1.03 | 112.5 | −23.5 | 7.13 | 24.11 | 12.92 | −6.12 | −0.47 | 3.81 |
| Togo | 14.98 | −15.1 | 2.68 | 5.74 | 82.10 | −62.2 | 5.89 | 25.60 | 4.48 | 2.78 | 3.25 | 0.75 | 115.2 | −30.9 | 6.07 | 22.9 | 10.67 | −5.85 | 0.76 | 3.57 |
| Tunisia | 17.74 | −1.45 | 5.07 | 3.29 | 31.70 | −18.7 | 4.05 | 11.08 | 3.58 | 1.34 | 2.46 | 0.77 | 28.40 | −9.05 | 6.30 | 8.13 | 10.80 | −4.53 | 2.66 | 4.05 |
| Zambia | 9.21 | −8.63 | 2.29 | 4.05 | 64.64 | −46.5 | 3.17 | 25.79 | 3.89 | 1.71 | 2.77 | 0.83 | 34.91 | −16.5 | 6.75 | 13.84 | 7.70 | −8.63 | −0.67 | 2.52 |

Source: Author's computation with underlining data from WDI. GDP: Gross domestic product, EC: Energy consumption

was estimated. The argument being put forward here is that there will be a regime shift if the value of EC goes beyond (or below) the threshold level. In essence, the threshold value helps to identify the optimal level of EC that would ensure stable and sustainable economic growth ceteris peribus. The result of the nonlinear model is the opposite of the linear model. For instance, Algeria and Senegal had positive and insignificant coefficients in the linear model, while the reverse is the case in the non-linear model. A similar explanation is adduced to Congo and Sudan, while Egypt, Gabon, Morocco, Zambia and Cameroon retained their sign coefficients.

Hansen (1996) argued that the statistical test for a nonlinear model does not follow the traditional tests, but uses statistics from his own large sample distribution function to transfer and calculate the asymptotic p value of a large sample, which is calculated by bootstrap method. These results are presented in the last column of Table 3 (LR Test). Results show the significance of the nonlinear model in countries under investigation with the exclusion of Botswana Gabon, Kenya, Senegal and South Africa.

An explanation to these varying results can be due to misspecification error. As such, the study further employed Ramsey RESET Test to examine linear specification to nonlinear specification. The null hypothesis is that linear model is the correct specification, while the alternate hypothesis assumes that nonlinear specification is correct. Even though results of the Ramsey RESET test are mixed, evidences of no misspecification error (i.e. rejection of null hypothesis of non-misspecification error in the linear model) were obtained in the case of Botswana, Gabon, and Kenya.

The study next splits the sample size into low and high-energy regime consumption levels and re-estimated equations 3 and 4, whose results are presented in Table 4. The results of this exercise can be summarized into four scenarios. Scenario 1 relates to low EC regime and low growth- a situation in which the low regime of EC retards growth i.e., there is a significant negative relationship in the nexus. Even though, the parameter for the high regime is positive, it could be said to be irrelevant due to its insignificance statistical level. Scenario 2 dwells on high- EC regime and high economic growth. Under this scenario, high regime of EC enhances economic growth, i.e. under the low regime, EC would not have meaningful impact on growth until it gets to a level where EC starts to impact positively on growth. Scenario 3 shows evidence of high- EC regime and low growth; while the last scenario does not take a definite position. An interesting result in this scenario is related to the fact that the obtained threshold level for EC in Botswana, Gabon and Senegal is the highest in the EC series. Hence, this limited us to examine the effect of EC when it is lower than the obtained threshold value. As such, the study left out these three countries in the sample splitting exercise.

The study found evidence of scenario 1 in Sudan and South Africa. Senegal, Algeria and Morocco validate the argument of scenario 2. Results show that Benin, Cote d'Ivoire, Egypt, Togo and Tunisia can be grouped into scenario 3, while Cameroon and Zambia are classified into scenario 4. Energy conservation policy would be more effective in scenarios 2 and 3. In order to economic growth

**Table 2: Empirical results for the linear model**

| Country | Constant | Capital | Labor | Export | Energy | $R^2$ | DW | R reset |
|---|---|---|---|---|---|---|---|---|
| Algeria | 1.1511 (0.343)* | 0.129 (0.030)* | −0.049 (0.053)* | 0.339 (0.058)* | 0.060 (0.049)* | 0.664 | 1.507 | 2.655 (0.074) |
| Benin | 3.332 (0.015)* | 0.025 (0.014) | 0.041 (0.086) | 0.132 (0.31)* | −0.030 (0.085) | 0.524 | 1.874 | 3.357 (0.087) |
| Botswana | 5.230 (0.626)* | 0.091 (0.016)* | −0.189 (0.109)*** | 0.252 (0.046)* | 0.181 (0.108) | 0.687 | 1.160 | 1.245 (0.293) |
| Cameroon | 2.151 (1.131)*** | 0.243 (0.052)* | −0.072 (0.270) | 0.034 (0.051) | 0.073 (0.277) | 0.518 | 1.458 | 3.178 (0.046) |
| Cote d'Ivoire | 1.280 (0.602)** | 0.073 (0.043)* | −0.020 (0.029) | −0.071 (0.043) | −0.010 (0.066) | 0.605 | 1.345 | 2.825 (0.029) |
| Egypt | 3.395 (3.915) | 0.048 (0.055) | −1.333 (1.257) | 0.088 (0.050)*** | −0.234 (0.368) | 0.644 | 1.717 | 2.909 (0.062) |
| Gabon | −1.732 (2.292) | 0.142 (0.022)* | 0.932 (0.801) | 0.265 (0.058)* | −0.074 (0.096) | 0.745 | 2.246 | 1.987 (0.245) |
| Kenya | 3.082 (1.196) | 0.065 (0.032)*** | −0.041 (0.538) | 0.033 (0.049) | −0.093 (0.261) | 0.164 | 1.250 | 1.654 (0.332) |
| Morocco | −0.218 (2.088) | 0.254 (0.109)** | 0.906 (0.666) | 0.107 (0.129) | 0.004 (0.283) | 0.558 | 2.993 | 3.646 (0.024) |
| Senegal | 0.417 (2.616) | 0.048 (0.026)*** | 0.721 (0.864) | 0.035 (0.046) | 0.032 (0.162) | 0.634 | 2.240 | 1.989 (0.099) |
| South Africa | 3.375 (1.223) | 0.131 (0.029) | −0.579 (0.394) | 0.147 (0.067)** | −0.004 (0.078) | 0.587 | 2.030 | 2.236 (0.075) |
| Sudan | 3.395 (3.914) | 0.048 (0.055) | −1.333 (1.257) | 0.088 (0.050)*** | −0.234 (0.368) | 0.744 | 0.630 | 2.250 (0.081) |
| Togo | −2.641 (3.526) | 0.130 (0.032)* | 1.247 (1.049) | 0.303 (0.069)** | 0.254 (0.200) | 0.598 | 2.280 | 2.314 (0.086) |
| Tunisia | 3.664 (1.280)* | 0.11 (0.036)* | 0.314 (0.502) | 0.009 (0.064) | −0.233 (0.095)** | 0.789 | 2.210 | 2.576 (0.068) |
| Zambia | 2.426 (5.039) | 0.048 (0.030) | −0.049 (1.594) | 0.040 (0.075) | 0.951 (0.548)*** | 0.648 | 2.203 | 3.186 (0.084) |

Source: Author's computation. Values in parenthesis represent the standard error while *,**,*** shows the level of statistical significance at 1% 5% and 10% respectively

**Table 3: Empirical results for the threshold variable**

| Country | Threshold | Cons | Capital | Labour | Export | Energy | $R^2$ | LR ratio |
|---|---|---|---|---|---|---|---|---|
| Algeria | 800 | 2.888 (0.685)* | 0.146 (0.026)* | 0.006 (0.015) | 0.346 (0.054) | −0.002 (0.001)** | 0.712 | 11.163 |
| Benin | 360 | 2.581 (0.014)* | 0.029 (0.014)*** | 0.020 (0.022) | 0.139 (0.030)* | 0.004 (0.002) | 0.579 | 13.097 |
| Botswana | 730 | 19.375 (4.074)* | 0.088 (0.014)* | −0.025 (0.023) | 0.178 (0.045)* | −0.015 (0.004)* | 0.769 | 2.464 |
| Cameroon | 410 | 1.031 (0.743) | 0.289 (0.051)* | −0.009 (0.033) | 0.009 (0.005) | 0.009 (0.004)** | 0.598 | 9.098 |
| Cote d'Ivoire | 390 | −1.615 (0.711)** | 0.072 (0.023)* | 0.028 (0.030) | −0.066 (0.043) | −0.002 (0.002) | 0.522 | 10.095 |
| Egypt | 450 | 7.856 (1.336)* | 0.092 (0.027)* | −0.614 (0.477) | 0.065 (0.036)*** | −0.004 (0.001)* | 0.672 | 9.397 |
| Gabon | 1220 | −0.914 (2.667) | 0.417 (0.021)* | 0.974 (0.803) | 0.289 (0.054)* | −0.000 (0.001) | 0.743 | 1.137 |
| Kenya | 440 | −50.910 (13.591)* | 0.055 (0.024)** | 0.239 (0.425) | 0.019 (0.038) | 0.116 (0.029)* | 0.488 | 2.283 |
| Morocco | 330 | −2.332 (2.632) | 0.184 (0.120) | 1.428 (0.773)*** | 0.119 (0.123) | 0.006 (0.005) | 0.696 | 14.097 |
| Senegal | 280 | 2.246 (2.502) | 0.048 (0.024)*** | 0.201 (0.814) | 0.010 (0.043) | −0.024 (0.010)** | 0.586 | 2.653 |
| South Africa | 2550 | 2.513 (1.701) | 0.137 (0.029)* | −0.536 (0.395) | 0.141 (0.064)** | 0.001 (0.001) | 0.595 | 2.489 |
| Sudan | 390 | 5.50 (2.218)** | 0.059 (0.028)** | 0.858 (0.792) | 0.016 (0.030) | −0.011 (0.004)** | 0.317 | 7.229 |
| Togo | 400-410 | −1.433 (3.734) | 0.135 (0.032)* | 1.040 (1.065) | 0.315 (0.069)* | −0.005 (0.004) | 0.596 | 16.203 |
| Tunisia | 500 | −3.224 (2.974) | 0.078 (0.037)** | 1.145 (0.635)*** | 0.008 (0.065) | 0.007 (0.002)* | 0.589 | 15.293 |
| Zambia | 650 | 0.042 (4.946) | 0.037 (0.027) | 1.830 (1.821) | −0.034 (0.083) | 0.009 (0.004)** | 0.605 | 15.294 |

Source: Authors' computation. Values in parenthesis represent the standard error while *,**,*** shows the level of statistical significance at 1% 5% and 10% respectively

**Table 4: The non-linear regression results of EC and economic growth**

| Country | Status | Cons | Capital | Labour | Export | EC | $R^2$ |
|---|---|---|---|---|---|---|---|
| Algeria | Above | 1.082 (0.177)* | 0.136 (0.012)* | −0.074 (0.031)** | 0.017 (0.076) | 0.078 (0.029)* | 0.752 |
| | Below | 3.089 (0.937)* | 0.147 (0.031)* | −0.067 (0.050) | 0.043 (0.012)* | −0.006 (0.036) | 0.908 |
| Benin | Above | 3.930 (0.191)* | 0.032 (0.008)* | 0.111 (0.033)* | 0.052 (0.013)* | −0.092 (0.032)* | 0.548 |
| | Below | 0.601 (4.172) | 0.011 (0.012) | 0.766 (1.165) | 0.029 (0.048) | 0.217 (0.102)** | 0.575 |
| Cameroon | Above | 16.460 (3.074)* | 0.285 (0.039)* | −4.166 (1.137)* | −0.036 (0.016)** | −1.273 (0.385) | 0.919 |
| | Below | 0.372 (0.631) | 0.175 (0.035)* | −0.233 (0.13)*** | 0.219 (0.037)* | 0.212 (0.143) | 0.54 7 |
| Cote d'Ivoire | Above | 1.061 (0.217)* | 0.159 (0.150)* | −0.014** (0.006) | −0.119 (0.011)* | −0.189 (0.039)* | 0.828 |
| | Below | 1.964 (2.311) | 0.067 (0.011)* | −0.223 (0.597) | 0.028 (0.035) | −0.052 (0.045) | 0.560 |
| Egypt | Above | 5.022 (0.671)* | 0.101 (0.202)* | −0.282 (0.317) | 0.034 (0.026) | −0.140 (0.067)** | 0.585 |
| | Below | 2.083 (1.983) | 0.282 (0.198) | 0.283 (0.102)** | 0.929 (0.893) | 0.001 (0.029) | 0.682 |
| Morocco | Above | 2.413 (0.091)** | 0.050 (0.104) | 0.852 (0.364)** | −0.052 (0.067) | 0.445 (0.217)** | 0.682 |
| | Below | −9.242 (2.400)* | 0.194 (0.062)* | 3.452 (0.718)* | 0.269 (0.084)* | 0.210 (0.212) | 0.501 |
| Senegal | Above | 1.920 (0.945) | 0.187 (0.096)** | 0.028 (0.103) | 0.221 (0.315) | 0.059 (0.011)* | 0.762 |
| | Below | 2.260 (1.190)*** | 0.048 (0.011)* | 0.193 (0.388) | 0.010 (0.020) | −0.013 (0.070) | 0.536 |
| South Africa | Above | 2.103 (1.093)** | 0.210 (0.192) | −0.837 (0.516) | 0.342 (0.103)* | −0.004 (0.036) | 0.586 |
| | Below | 1.837 (1.038) | 0.028 (0.092) | 0.273 (0.103)** | 0.193 (0.103) | −0.023 (0.011)** | 0.639 |
| Sudan | Above | −2.678(3.104) | 0.057(0.028)*** | 2.239(1.152)*** | 0.013(0.032) | 0.020(0.348) | 0.563 |
| | Below | 7.986(0.259)* | −0.115(0.032)* | 1.478(0.212)* | −0.151(0.025)* | −0.572(0.064)* | 0.672 |
| Togo | Above | 1.246(1.167) | 0.139(0.060)** | −0.201(0.433) | 0.172(0.091) *** | −0.507(0.118)* | 0.593 |
| | Below | −13.520(9.156) | 0.130(0.039)* | 4.701(0.670) | 0.317(0.082)* | −0.093(0.317) | 0.715 |
| Tunisia | Above | 3.625(1.254)* | 0.102(0.036)* | 0.402(0.496) | −0.019(0.066) | −0.184(0.099)*** | 0.683 |
| | Below | 4.818(1.333)* | 0.151(0.056)** | 0.294(0.192) | 0.219(0.052)* | −0.286(0.162) | 0.833 |
| Zambia | Above | −12.368(8.188) | 0.054(0.031) | 3.916(2.411) | −0.137(0.115) | 0.521(0.706) | 0.680 |
| | Below | 0.552(4.043) | −0.139(0.091) | 0.687(1.325) | 0.153(0.101) | 0.251(0.549) | 0.727 |

Source: Author's computation. Values in parenthesis represent the standard error while *,**,*** shows the level of statistical significance at 1% 5% and 10% respectively. EC: Energy consumption via EC, industrialization policy that is energy efficient must be formulated in Sudan and South Africa. This is to avoid greenhouse gas emissions. We also found that Benin, Cote d'Ivoire, Egypt, Togo and Tunisia validate EKC hypothesis while Algeria, Morocco and Senegal refute the hypothesis.

## 5. CONCLUSION AND POLICY IMPLICATIONS

Using data set for 12 countries in Africa for the periods 1980-2010, the study considers the possibility of capturing both the linear and non-linear effect of EC on economic growth. As for the linear effect, the paper adopts ordinary least squares approach, while a recent econometric procedure of threshold auto regression of Hansen (1996) was employed for the nonlinear model. The data series used in this study is collected from world development indicator database of the World Bank.

The EC-growth relationship in most of the countries under study is negative, though insignificant. Ramsey RESET Test results show that the linear model suffers from misspecification error. Results of the non-linear specification show that there is a positive externality effect for high levels of EC in Algeria, Morocco and Senegal. The high EC in Benin, Cote d'Ivoire, Egypt, Togo and Tunisia could be considered as growth drag, hence, leading to a negative externality.

The implication of our findings is that structural change in the EC-growth nexus is caused by the existence of an EC threshold, which must be taken into consideration when modeling economic growth and EC (Lee and Chang, 2007). From a policy perspective, there is evidence of growth effect in Algeria, Morocco and Senegal. This suggests that EC plays an important role in the growth pattern of these countries. Government in these countries should try to cut their energy demand without necessarily inhibiting growth. This can be achieved by making a paradigm shift to the adoption of cleaner and modern technologies. As such, emphasis should be laid on reliance on wind, solar, nuclear and other forms of renewable sources of energy. The inability of Benin, Cote d'Ivoire, Egypt, Togo and Tunisia to achieve growth despite its high EC could be related to aging infrastructure and facilities, inefficiency and overload which lead to constant interruption. Inefficient use of energy is also a plausible and perhaps, an important cause in Cote d'Ivoire and Togo. Hence, government should set in policies to curb these incidences. Overall, policymakers should formulate policies that are more energy efficient to control greenhouse gas emissions. Hence, the primary objective of African government should be to increase energy efficiency.

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