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# Empirical Analysis of Electricity Consumption, $CO_2$ Emissions and Economic Growth: Evidence from Cameroon

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**ABSTRACT**

This paper investigates the relationship between electricity consumption, carbon emissions and economic growth in Cameroon during the period 1971-2014. Results from autoregressive distributed lag bounds test, confirms a positive and significant short-run as well as a long-run relationship between $CO_2$ emissions and economic growth. Prior to the application of Toda and Yamamoto Granger causality test, the results reveal a unidirectional causality running from $CO_2$ emissions to economic growth. Furthermore, the environmental Kuznets curve hypothesis shows existence of an inverted U-shaped curve relating carbon emissions rise to the continuous economic evolvement in Cameroon. However, a neutrality hypothesis holds between electricity consumption and economic growth for the period under study. The government energy policy regulations should, hereby be geared at reducing greenhouse gas emissions from thermal power plants by boosting the evolution of other sources of renewable energy, which will lead to the amelioration of electricity access rates in the country.

**Keywords:** Economic Growth, Energy Development, Carbon Emissions, Energy Policy
**JEL Classifications:** O13, Q43

## 1. INTRODUCTION

Energy production is an important input to the economies of developed, emerging and developing countries. Projections done by the US Energy Information Administration (EIA), expects a rise in energy consumption from 2015 to 2040 with a major increase of 41% in non-OECD countries and 9% in OECD countries (EIA, 2017). Cameroon has in recent years known a considerable industrial transformation, which is favored by its strategic geographic position within the Gulf of Guinea, coupled with flexible business policies, political stability, available raw materials and an accessible labor market. These factors have contributed in attracting both national and foreign business operators to develop activities both in the primary, secondary and tertiary industrial sectors in the country. Nevertheless, the country still faces chronic power problems associated with insufficient electric power generation capacity, ageing electric transmission networks, and high cost of electricity, which all constrain economic development. As a result of these shortcomings, the growing population and industrial stakeholders rely on alternative energy sources such as; diesel oil generators, wood, charcoal etc. to satisfy their energy demands. However, the prolonged usage of such essences produce effects which favors environmental degradation. The challenge therefore lies in providing affordable, clean, and reliable energy sources that promote industrialization and sustainable development in the country. A study done by Tamba et al. (2017) affirms that in the current context electricity consumption in Cameroon has no effect on its economic development, due to the numerous problems plaguing the sector.

Recently researches have been focused on panel data to understand the factors that affect electricity consumption, as well as encourage economic recession and the ramifications of over-dependence on fossil fuels for electricity generation on the environment. The outcome of these studies proved that rapid industrialization in some countries tend to promote greenhouse gas (GHG) emissions, but environmental degradation decreases after a certain threshold value of economic development is reached. Is this situation true for Cameroon? And is the Environmental Kuznets curve (EKC) hypothesis applicable in Cameroon. However, no research till date has tested this situation for the case of Cameroon.

The present study investigates the secondary effects of electricity consumption on the environment and the economy as a result of using alternative energy sources in Cameroon. The rest of this paper is structured as follows; section two presents the literature review, followed by section three which expounds on electricity consumption and environmental pollution in Cameroon, section four carries on the data and methodology, section five provides empirical results. And the final section of the paper suggests some policy implications and concluding remarks.

## 2. LITERATURE REVIEW

In recent years, the correlation between electrical energy consumption, carbon emissions and economic growth has been subject to several empirical researches in energy economics; (Saboori and Sulaiman, 2013) (Cowan et al., 2014), (Tamba et al., 2014b), Salahuddin et al. (2018), (Balsalobre-Lorente et al., 2018) and Al-Mulali et al. (2019). The absence of a harmonic set of ideas to corroborate with the results of past studies, led to a rise in the interest from several economists to understand the reverse effect of one variable on the other. This section of the paper centers on revealing the main contributions from works which linked energy consumption to environmental pollution and economic growth. Generally based on their results we can classify these researches on the energy (electricity consumption), environmental pollution - economic growth nexus into four main groups; firstly results which demonstrate a one-way causality relationship running from electricity consumption to economic growth or $CO_2$ emissions (growth hypothesis), this suggest that the country`s economy is energy dependent. Secondly, results describing causality relations in the reverse direction running from economic growth to electricity consumption (conservation hypothesis) gives indications of the limited dependence of the country`s economy on the electrical energy production. Thirdly, a feedback hypothesis is described if there exists a reciprocal (bidirectional) causality relation between the variables, it eventually signifies that the two variables are complementary and that an increment in electricity consumption spurs economic growth and vice-versa. And fourthly the absence of causality also known as the neutrality hypothesis describes a situation whereby energy policies will have no influence on economic output (Ozturk, 2010).

The literature on the electricity consumption, environmental pollution and economy growth nexus in Cameroon, is scanty and the few studies done could be classified into two main sets based on the number of variables, time period data and methodology used for these studies. Early empirical research works on Cameroon focused on building bivariate analysis models using two major indicators; diesel oil consumption and economic growth. Hydrocarbons production has for long been a major source of income for the country, Wandji (2013) adopted a three-step empirical theory to test the causality relationship between energy consumption and economic growth during the 1971-2009 period. The results outlined a unidirectional causality running from diesel oil consumption to economic growth. Similarly, works from Tamba et al. (2012) examined the empirical relationship between diesel consumption and economic growth in Cameroon for the period 1975-2008 results indicated a bidirectional causality between both variables in the long-run. The results of their investigations ascertained the dependence of the country`s economy on fossil fuels. The second set of studies from; (Tamba et al., 2014a) and (Tamba et al., 2014b) were based on a multivariate framework using vector error correction model (VECM) to analyze the relationship between carbon emissions, diesel consumption and economic output. The outcome of the research revealed the existence of a bi-directional causality in both the long-run and short-run direction between carbon emissions and economic output. And finally, Nkengfack et al. (2014) investigated the effect of electricity consumption, urbanization and economic growth on carbon emissions using data from 1971 to 2011. The results suggest that carbon emissions response positively to changes in electricity consumption, economic growth and urbanization in Cameroon. Though, they estimated an autoregressive distributed lag (ARDL) model for cointegration and a VECM was used to test the short-run causality between the variables.

The study of causal relationships between energy consumption and economic growth started with the pioneer works from Kraft and Kraft (1978) in the United States of America (USA) using data from 1947 to 1974, they established the existence of a unidirectional causality running from gross national product to energy use. The results indicate that energy conservation policies have no unfavorable effects on economic growth. However, this research has been challenged by studies from Akarca and Long (1980) and Yu and Choi (1985) which noticed a neutral hypothesis between the variables. More recent studies from Stern (2000) developed a VAR and Lee (2006) applied the Toda and Yamamoto method to understand the direction of causality between energy consumption and economic growth in the USA. Conclusions from their works confirm a bidirectional relationship between energy consumption and gross domestic product (GDP) in the United States, a unidirectional causality was found for the same variables in Canada, Belgium, Netherlands and Switzerland. A series of research works have been done in Europe on the electricity consumption-economic growth nexus, with most having conflicting results. Ozturk and Acaravci (2010) adopted panel data from 15 European Union transition countries to examine any long-run relationship and causality between electricity consumption and economic growth. This study utilized the Pedroni panel cointegration tests for the 1990-2006 period, and the empirical results show no long-term equilibrium relationship between electricity consumption and real GDP per capita for the 15 European countries.

By developing a dynamic VECM, Ozturk and Acaravci (2010) studied the linkage between electric power consumption per capita and real GDP per capita in Albania, Bulgaria, Hungary and Romania. Only Hungary had conclusive results in this study, with evidence of a long-run relationship and bidirectional causality between energy use and GDP per capita. Studies done in emerging countries notably in the Asian continent, depict some pertinent correlation between electricity consumption and output. In China, Shengfeng (2012) examined the short and long-run causal relationship between electricity consumption and real GDP for the period 1953-2009, results from this study revealed a unidirectional causality from electricity consumption to economic growth and implied that electric power supply can to some extent become the restricting factor to economic growth in China. On the contrary, a recent study by Liu et al. (2017) investigated the detailed quarterly and sectoral nexus between electricity consumption and economic growth in Beijing. The results show that at a reduced level there is a unidirectional causality running from GDP to electricity consumption. Bayar and Özel (2014) used panel empirical analysis to demonstrate a bi-directional causality between economic growth and electricity consumption for 21 emerging countries. The outcomes of this study are in phase with works from: (Gurgul and Lach, 2012), (Hu and Lin, 2013), (Ogundipe and Apata, 2013) and (Nazlioglu et al., 2014).

Several empirical theories related to African countries, be it single-country or multi-country studies have concentrated efforts in understanding the cause to effect relationship between electricity consumption, environmental degradation and economic growth. In some cases country based empirical studies tend to have controversial results on the nature of the relationship among these variables. The disagreements of results from previous studies can be attributed to the use of differing time periods, methodology and additional variables in conducting the empirical analysis. Ogundipe and Apata (2013) examines the relationship between electricity consumption and economic growth in Nigeria for the period 1980-2008, which results registered a bidirectional causal relationship between these variables. On the contrary, Akinwale et al. (2013) utilized a vector auto regressive (VAR) and error correction model (ECM) to test the causality between real GDP and electricity consumption in Nigeria for a longer period 1970-2005, and the result of this work confirms a unidirectional causality from real GDP to electricity consumption without a feedback effect. The methods and conclusions of studies which are highly correlated with our investigation are listed in Table 1.

Akinlo (2009) equally worked on data time series of Nigeria for almost the same period 1980-2006, using the Augmented Dickey-Fuller (ADF) test and the ECM to investigate the Granger causality between real GDP and electricity consumption. The results shows a unidirectional causality running from electricity consumption to economic growth in Nigeria. Likewise,Wolde-Rufael (2006) worked on panel data for 17 African countries among which Cameroon, using ARDL and Toda Yamamoto approach to test the effect of electricity consumption on economic growth. According to Jumbe (2004), there is no causality relationship between economic growth and energy consumption using standard Granger causality test and error correction model (ECM) data from Malawi for the period 1970-1999. Solarin (2011) employ bound test for cointegration and Granger causality, the results satisfy a unidirectional causality from electricity consumption to the real GPD in Botswana. Furthermore, Ouedraogo (2013) explored the relationship between electricity consumption and growth for 15 ECOWAS countries, brings out the evidence of a long run unidirectional causality relationship running from electricity consumption to real GDP exists. Kouakou (2011) investigated the influence of electric power use on Ivory coast economy using an error correction model, and his results revealed a feedback hypothesis between economic growth and electricity consumption.

For Burkina Faso, Ouédraogo (2010) applies the ARDL bound test and hence demonstrated that a bidirectional causality exist between electricity consumption and economic growth. Odhiambo (2009a) and Odhiambo (2009b) respectively used the ARDL bound test for empirical analysis in South Africa and Tanzania. The causality test proved there is a unidirectional causality from total energy consumption to economic growth in Tanzania, and a bidirectional causality between per capita electricity consumption and per capita GDP in South Africa. Bélaïd and Abderrahmani (2013) selected a multivariate cointegration approach and VECM, to present evidence of short run and a strong bidirectional causal relationship between electricity and real GDP in Algeria. Karanfil and Li (2015) explored the long and short-run dynamics using panel data of per capita electricity consumption and per capita GDP for 160 countries. The traditional EKC hypothesis was applied in a series of pioneer works to analyze the relationship between economic growth and environmental degradation parameters (Grossman and Krueger, 1991), (Grossman and Krueger, 1995), (Holtz-Eakin and Selden, 1995) and (Moomaw and Unruh, 1997). The empirical results from these studies denotes an inverted U-shaped curve, which describes a direct relationship between environmental degradation and economic growth but changes after a threshold value of economic output is attained. Balsalobre-Lorente et al. (2018) analyzed the contribution of economic growth, renewable electricity consumption and natural resources on carbon emissions in 5 EU-member state countries. It is worth noting that, few single-country studies in Africa have utilized environmental pollutants as an additional parameter to understand the relationship between electricity consumption and economic growth.

Bah and Azam (2017) used ARDL and Toda Yamamoto approach to explore the causal relationship between electricity consumption, economic growth and $CO_2$ emissions in South Africa. The main findings from this work shows existence of no causality relationship between electricity consumption and economic growth in South Africa, which suggests that government policies should be geared at augmenting investments in the electric power generation sector. Nevertheless, there is a unidirectional causality from $CO_2$ emissions to electricity consumption and therefore transformation of renewable energies is essential to reduce environmental degradation. In addition, Akpan and Akpan (2012) applied VECM framework to examine the long-run and causal relationship between electricity consumption, carbon emissions and economic growth in Nigeria. Thus, Menyah

**Table 1: An Overview of some selected studies on the energy (electricity) consumption, $CO_2$ emissions-economic growth nexus**

| Authors | Period | Countries | Methods | Results |
|---|---|---|---|---|
| North America and Europe | | | | |
| Kraft and Kraft (1978) | 1947-1974 | USA | Sims causality test | GNPusal |
| Stern (2000) | Post war period | USA | VAR | ENGt wa |
| Lee (2006) | 1960-2001 | G-11 countries | Toda Yamamoto | ENG↔GDP for USA |
| Ozturk and Acaravci (2010) | 1980-2006 | Hungary | ARDL and VECM | ENG↔GDP |
| Acaravci and Ozturk (2010) | 1990-2006 | 15 EU countries | ECM | Neutrality-hypothesis |
| Asia and Middle East | | | | |
| Shengfeng (2012) | 1953-2009 | China | VECM | ELEC→GDP |
| Ashraf et al. (2013) | 1960-2008 | Pakistan | Engel and Granger | ELEC→GDP |
| Bayar and Özel (2014) | 1970-2011 | 21 emerging countries | Granger causality test | GDP→ELEC |
| Liu et al. (2017) | 2005-2016 | China | Granger causality test | GDP→ELEC |
| Africa | | | | |
| Jumbe (2004) | 1970-1999 | Malawi | VECM | ELEC↔GDP |
| Wolde-Rufael (2006) | 1971-2001 | 17 African countries | ARDL and Toda Yamamoto | 6 countries GDP→ELEC |
| Odhiambo (2009a) | 1971-2006 | Tanzania | ARDL bound test and ECT | ELEC→GDP |
| Odhiambo (2009b) | 1971-2006 | South Africa | ECM | ELEC↔GDP |
| Akinlo (2009) | 1980-2006 | Nigeria | ARDL | ELEC→GDP |
| Ouedrago (2010) | 1968-2003 | Burkina faso | Bounds test and VECM | ELEC↔GDP |
| Menyah and Wolde (2010) | 1965-2006 | South Africa | ARDL and Toda Yamamoto | $CO_2$→GDP |
| Kouakou (2011) | 1971-2008 | Ivory coast | Bounds test and VECM | ELEC↔GDP |
| Solarin (2011) | 1980-2008 | Botswana | Bounds test and causality | ELEC→GDP |
| Akpan and Akpan (2012) | 1970-2008 | Nigeria | ARDL and VECM | $CO_2$→ELEC |
| Ouedraogo (2013) | 1980-2008 | 15 ECOWAS countries | Panel cointegration | ELEC→GDP |
| Wandji (2013) | 1971-2009 | Cameroon | ECM | Neutrality-hypothesis |
| Akinwale et al. (2013) | 1970-2005 | Nigeria | VAR and VECM | GDP→ELEC |
| Ogundipe and Apata (2013) | 1980-2008 | Nigeria | Cobb douglas | ELEC↔GDP |
| Bélaïd and Abderrahmani (2013) | 1971-2010 | Algeria | VECM | ELEC↔GDP |
| Cowan et al. (2014) | 1990-2010 | BRICS countries | Panel causality | GDP→$CO_2$ |
| Tamba et al. (2014) | 1975-2008 | Cameroon | VECM | $CO_2$↔GDP |
| Nkengfack et al. (2014) | 1971-2011 | Cameroon | ARDL and VECM | GDP↔$CO_2$ |
| Karanfil and Li (2015) | 1980-2010 | 160 countries | Panel Cointegration | Neutrality-hypothesis |
| Bah and Azam (2017) | 1971-2012 | South Africa | ARDL and Toda Yamamoto | $CO_2$→ELEC |
| Tamba et al. (2017) | 1971-2013 | Cameroon | VAR and Granger causality | Neutrality-hypothesis |
| Appiah (2018) | 1960-2015 | Ghana | ARDL and Toda Yamamoto | ENG↔$CO_2$ |

ELEC: Electricity consumption, ENG: Energy consumption, GNP: Gross national product, GDP: Gross domestic product, $CO_2$: Carbon dioxide emissions →, ↔ are respectively unidirectional causality and bidirectional causality. VECM: Vector error correction model, ARDL: Autoregressive distributed lag, ECT: Error correction term, VAR: Vector autoregressive model

and Wolde-Rufael (2010) applied the bound test approach to examine the long-run and the causal relationship between economic growth, pollutant emission and energy consumption for South Africa for the period 1965-2006. This work found evidence for a unidirectional Granger causality running from pollution emissions to economic growth as well as from energy consumption to economic growth. Appiah (2018) used both Johansen and Julius-Johansen approach, and ARDL bounds test to verify cointegration between energy consumption, $CO_2$ emissions and economic growth. This research equally applied Toda Yamamoto and Granger causality tests, which reveals there is feedback causality between energy consumption and $CO_2$ emissions. Some multi-country studies such as that of Cowan et al. (2014) considered all three parameters using panel data for the period 1990-2010, from BRICS countries (Brazil, Russia, India, China and South Africa). Hence a neutrality hypothesis holds for Brazil, India and China, which suggests that electricity consumption policies will not affect economic growth and vice versa. Under this study, carbon emissions and economic growth nexus demonstrates divergent results; a feedback hypothesis for Russia, a unidirectional causality from GDP to $CO_2$ emissions in South Africa and the reverse relationship in Brazil is found.

## 3. ELECTRICITY CONSUMPTION AND ENVIRONMENTAL DEGRADATION SITUATION IN CAMEROON

The power sector in Cameroon is plagued by several challenges attributed to the lack of adequate regulation and institutional setting for off-grid, renewable energy and energy efficiency (Fotsing et al., 2014). The national electricity supplier ENEO is struggling to meet the demand in quantity and quality of electrical energy delivered particularly during peak periods. Among the factors restricting adequate supply of electricity in the country, is the persisting issue of ageing energy infrastructures which lead to frequent transmission losses and power load shedding. Despite this situation, the number of consumers connected to the national grid continually increases and by 2014 more than 951,500 inhabitants were supplied by the national electricity company (MINEE, 2015). In 2015, the rate of electricity consumption in Cameroon was estimated at 317.43 KWh/capita and is definitely projected to increase to 422.6 KWh/capita in 2025 (FUSS, 2013). The Northern, Littoral, Centre and Western regions are highly dense in population and account for the greatest proportion of electrical power consumption in the country. More than 63% of this energy is provided by ENEO for public consumption, 20.62% of electricity consumed is from onshore thermal stations, and 13.27% represents consumptions from fraudulent connections on the public network (MINEE, 2015). As seen in Figure 1, only 1% of electricity consumption is generated from renewable energy (RE) sources. However with increase population growth rate and rapid industrialization, the demand for electrical energy is continuously on a rise and the national electricity production is therefore insufficient to satisfy this demand.

Consequently, the population has to require for alternative sources of energy such as; wood, petrol and diesel oil as fuel for cooking, heating and lighting in households which eventually have toxic effects on the environment. According to statistics from IEA (2018), the transport sector is responsible for 61% of $CO_2$ emissions released against 11% for the construction and manufacturing industry in Cameroon. As seen in Figure 2, there is a gradual increase since 2005 to 2016 in the amount of $CO_2$ emissions per inhabitant from fuel combustion (IEA, 2018). The major sources accountable for the greater proportion of air pollution in Cameroon are; wood still used by the population in remote rural areas as a source for heating and cooking, fuel used in the transport sector and industries as a source of heat. Furthermore,

**Figure 1:** The different sources of electricity consumption in Cameroon (modified from; MINEE, 2015)

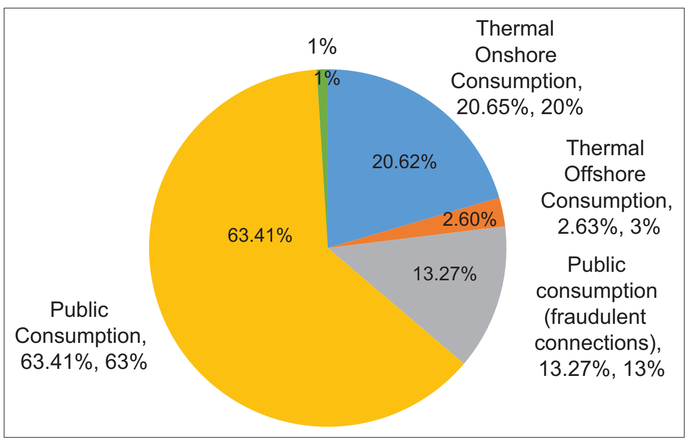
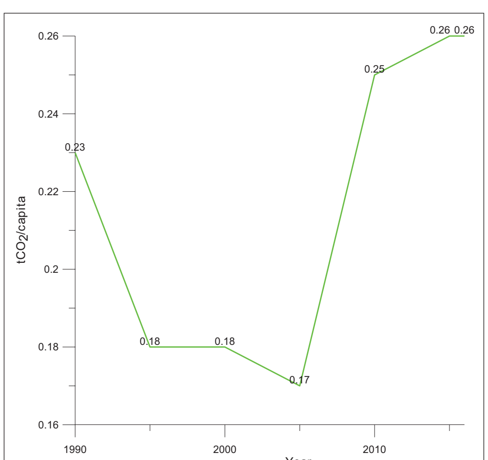



**Figure 2:** Carbon emissions per capita from fuel combustion in Cameroon from 1990 to 2016




the government hasn`t established a general inventory of emissions related to electric power generation especially due to the use of thermal power plants. Therefore, efforts have to be continuously made by the government to attain expected economic growth while maintaining GHG emissions at very low percentages.

## 4. DATA AND METHODOLOGY

### 4.1. Data

The time series used in the present analysis represents annual data of; electricity consumption (ELEC) per capita in KWh, GDP (per capita) in constant 2010 US$ and $CO_2$ emissions ($CO_2$) in metric tons per capita which covers the period 1971-2014 in Cameroon. Due to unavailability of data exclusive to carbon emissions from diesel or thermal power plants used for electric power generation, $CO_2$ emissions data used in this study are attributable to emissions from the combustion of fossil fuels in power plants and the manufacture of cement. Therefore, the data can be used as a proxy and is representative of emissions from power plants. All the time series were obtained from the World Bank's development indicators (World-Bank, 2019) online database and they are all expressed as natural logarithms, to reduce the effect of heteroskedasticity on results and enable a more stable variance of the data.

### 4.2. Methodology

This study builds a comparative framework to previous works from Tamba et al. (2017) to analyze the causality relationship between electricity consumption and economic growth. Employing techniques such as; the ADF test and the Phillips and Perron (1988) PP test to check the presence of unit roots, the ARDL test for cointegration and finally, the Toda and Yamamoto (1995) Granger causality approach is implemented to define the direction of causality between the variables. Furthermore, this study investigates the relationship between carbon emissions and economic growth in Cameroon for the 1971-2014 period using the EKC.

#### *4.2.1. Stationary tests*

Prior to running econometric analysis, it is important to determine the most appropriate form of trend in the data. In a situation where the data has a trend pattern, therefore the data must be transformed to stationary form before cointegration and causality analysis is performed. The utilization of non-stationary data usually causes spurious regressions in the form of white noise which may affect the test results. Hence to avoid this, a unit root test is conducted to decide the order of integration of the variables. This study applies both the Dickey and Fuller (1979) and the Phillips and Perron (1988) tests to check the existence of unit roots. Using different test methods to compare our stationary results is a good way of testing the sensitivity of our results. The PP test adds more credibility to the stationary test results, by ignoring any serial correlation in the test regression. It ensures a higher autocorrelation consistency and heteroskedasticity correction of the data time series. Therefore the application of both the ADF and PP tests ensures a robust model for checking the order of integration of the data used in this analysis. The ADF regression model used in this study is expressed below:

$$\Delta Y_t = \alpha_0 + \gamma Y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta Y_{t-i} + \mu_t \quad (1)$$

Where $\Delta Y_t = Y_t - Y_{t-1}$, $Y_t$ represents one of the three variables of electricity consumption (ELEC), $CO_2$ emissions ($CO_2$) or economic growth (GDP), $\alpha_0$ is the intercept, $\gamma$ is a constant and $\mu_t$ is a stochastic error term. The regression equation for the PP test is shown below:

$$\Delta Y_t = \propto + \delta Y_{t-1} + e_t \quad (2)$$

Where $\alpha$ is the intercept, $\delta$ is a constant and $e_t$ is the error term.

*4.2.2. Cointegration test*

After confirming that all the variables used in this study are integrated of the same order, the next step is to test for the presence of long-run equilibrium relationship between the variables. It is a relevant technique used to uncover long-run relationships between variables that are usually concealed by the noise of short term fluctuations. Pioneer works done by Engle and Granger (1987) and Johansen and Juselius (1990) contributed enormously to the comprehension of this regression method in econometrics analysis studies. This paper applies the ARDL test of Pesaran et al. (2001) for cointegration, which is essential in recovering the relevant long-run relation among the underlying variables that was lost on differencing. The ARDL bounds test is preferred here, over other traditional cointegration methods because it provides unbiased estimates of the long-run model and it is suitable to analyze variables with small data sizes irrespective of the order of integration of these variables. The initial step in the ARDL approach is to build a model with each variable of $ln(GDP)$, $ln(ELEC)$ and $ln(CO_2)$ as the dependent variable and the introduction of unrestricted lag of the regressors. Therefore, the various ARDL models with each endogenous and exogenous variables are defined below as follows:

Model 1:

$$\Delta lnELEC = \propto_1 + \sum_{i=1}^{n} \alpha_i \Delta lnELEC_{t-i} + \sum_{a=0}^{n} \alpha_a \Delta lnGDP_{t-a} + \sum_{b=0}^{n} \alpha_b \Delta lnCO_{2t-b} + \gamma_1 lnELEC_{t-1} + \gamma_2 lnGDP_{t-1} + \gamma_3 lnCO_{2t-1} + \varepsilon_{1t} \quad (3)$$

Model 2:

$$\Delta lnGDP = \delta_1 + \sum_{i=1}^{n} \delta_i \Delta lnGDP_{t-i} + \sum_{a=0}^{n} \delta_a \Delta lnELEC_{t-a} + \sum_{b=0}^{n} \delta_b \Delta lnCO_{2t-b} + \beta_1 lnGDP_{t-1} + \beta_2 lnELEC_{t-1} + \beta_3 lnCO_{2t-1} + \varepsilon_{2t} \quad (4)$$

Model 3:

$$\Delta lnCO_2 = \partial_1 + \sum_{i=1}^{n} \partial_i \Delta lnCO_{2t-i} + \sum_{a=0}^{n} \partial_a \Delta lnGDP_{t-a} + \sum_{b=0}^{n} \partial_b \Delta lnELEC_{t-b} + \varphi_1 lnCO_{2t-1} + \varphi_2 lnGDP_{t-a} + \varphi_3 lnELEC_{t-b} + \varepsilon_{3t} \quad (5)$$

Where $\alpha_1$, $\delta_1$, and $\partial_1$ are unrestricted intercepts, $\alpha_n$, $\delta_n$, and $\partial_n$ ($n = i, a, b$...) denotes the short-run coefficients, $\gamma$, $\beta$ and $\varphi$ represents the long-run coefficients, and $\varepsilon_{it}$ ($i = 1...3$) is a white noise error term. In order to verify the existence of a long-run relationship among the considered variables initially, the hypothesis that the coefficients of the lag level variables are zero needs to be tested. The null hypothesis of non-existence of a long-run relationship is defined as follows: $H_0$:$\gamma_1=\gamma_2=\gamma_3=0$ (for model 1), $H_0$: $\beta_1=\beta_2=\beta_3=0$ (for model 2) and $H_0$: $\varphi_1=\varphi_2=\varphi_3=0$ (for model 3). The alternative hypothesis for the existence of a long-run relationship is expressed as: $H_0$: $\gamma_1\neq\gamma_2\neq\gamma_3\neq0$ (for model 1), $H_0$: $\beta_1\neq\beta_2\neq\beta_3\neq0$ (for model 2) and $H_0$: $\varphi_1\neq\varphi_2\neq\varphi_3\neq0$ (for model 3).The above hypotheses are tested by means of the F-statistic (Wald statistic), based on the number of variables used and if the ARDL model has either a trend or an intercept. Regardless of the order of integration of the variables; whether I(1) or I(0), the critical values of the calculated F-statistics are usually referred from Pesaran et al. (2001). However, it is recommended that for studies handling economic data series with sample sizes ranging between 30 and 80, it is preferable to use the set of critical values provided by Narayan (2005). Hence, if the calculated F-statistics is below the lower bound critical value then the null hypothesis ($H_0$) will not be rejected, indicating that no long-run relationship exist between the variables. On the contrary, if the computed F-statistic is greater than the upper bound critical value then $H_0$ is rejected, which means the variables are cointegrated. In case, the calculated F-statistics falls between the lower and upper bound critical values, therefore the results of the test will be inconclusive.

*4.2.3. Granger causality test*

In past years many Granger-type causality tests have been derived and implemented, including Granger (1969) and Sims (1972) to test the direction of causality between variables. Pretesting for stationarity and cointegration of the economic time series data is required before the appropriate causality test is selected. Early methods of testing causality relationships had some shortcomings such as; prior acknowledgement of the presence of cointegration before running a causality test and in addition most of these methods had less robust framework in examining causality relations. Shortcomings which could be overcome by adopting the Toda and Yamamoto (1995) test to determine the direction of causality between the variables. The Toda and Yamamoto approach develop a VAR in levels of the variables thereby reducing the risk of wrongly identifying the order of integration of the series Mavrotas and Kelly (2001), paying little or no knowledge to the integration and cointegration properties of the data in hand. The causality test is ran based on the Wald criterion, assuming that the standard asymptotic theory holds. Therefore, the order of integration ($d_{max}$) of the process should not exceed the optimal lag length (k) of the model. The determined lag length k is used to estimate a VAR model of k + $d_{max}$ order between the variables (Toda and Yamamoto, 1995).

In this paper the models of Granger non causality test, for electricity consumption, $CO_2$ emissions and GDP are expressed as:

$$lnELEC_t = \propto_0 + \sum_{i=1}^{k} \propto_{1i} lnELEC_{t-i} + \sum_{j=k+1}^{d_{max}} \propto_{2j} lnELEC_{t-j} + \sum_{i=1}^{k} \beta_{1i} lnGDP_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} lnGDP_{t-j} + \sum_{i=1}^{k} \gamma_{1i} lnCO_{2t-i} + \sum_{j=k+1}^{d_{max}} \gamma_{2i} lnCO_{2t-j} + \varepsilon_{1t} \quad (6)$$

$$lnGDP_t = \propto_0 + \sum_{i=1}^{k} \propto_{1i} lnELEC_{t-i} + \sum_{j=k+1}^{d_{max}} \propto_{2j} lnELEC_{t-j} + \sum_{i=1}^{k} \beta_{1i} lnGDP_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} lnGDP_{t-j} + \sum_{i=1}^{k} \gamma_{1i} lnCO_{2t-i} + \sum_{j=k+1}^{d_{max}} \gamma_{2i} lnCO_{2t-j} + \varepsilon_{2t} \quad (7)$$

$$lnCO_{2t} = \propto_0 + \sum_{i=1}^{k} \propto_{1i} lnELEC_{t-i} + \sum_{j=k+1}^{d_{max}} \propto_{2j} lnELEC_{t-j} + \sum_{i=1}^{k} \beta_{1i} lnGDP_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} lnGDP_{t-j} + \sum_{i=1}^{k} \gamma_{1i} lnCO_{2t-i} + \sum_{j=k+1}^{d_{max}} \gamma_{2i} lnCO_{2t-j} + \varepsilon_{3t} \quad (8)$$

In Eq. (8) a unidirectional Granger causality is found from $lnGDP_t$ to $lnELEC_t$ if $\beta_{1i} \neq 0$, similarly, there is unidirectional causality from $lnCO_{2t}$ to $lnGDP_t$ in Eq. (9) if $\gamma_{1i} \neq 0$ and unidirectional causality from $lnELEC_t$ to $lnCO_{2t}$ in Eq. (10) if $\alpha_{1i} \neq 0$. Here $\varepsilon_1$, $\varepsilon_2$ and $\varepsilon_3$ are disturbance terms with no mean and are considered to be uncorrelated.

#### *4.2.4. EKC model*

The EKC is a hypothesized inverted U-shaped curve which describes the relationship between per capita environmental emissions and per capita income for a given country at a specific time. This study uses a quadratic equation to test the relationship between carbon emissions and economic growth, the EKC regression model is expressed as;

$$lnCO_{2it} = \propto_{it} + \beta_1 lnGDP_{it} + \beta_2 lnGDP_{it}^2 + \varepsilon_{it} \quad (9)$$

Where α is a constant, $\beta_1$ and $\beta_2$ are respectively coefficients of economic growth per capita, ε is the error term, the subscripts *t* and *i* respectively stand for time and country. If an EKC exists, $\beta_1 > 0$ and $\beta_2 < 0$ and the threshold point (turning point) which represents the point where carbon emissions are at a maximum is given by:

$$t = exp\left(-\frac{\beta_1}{2\beta_2}\right) \quad (10)$$

We attempt to estimate both the fixed effect and random effect model for the case of Cameroon in this study. A Hausman (1978) test is used to determine the inconsistency in the random-effect model, if there is a considerable difference between the slope parameters of these two models it indicates that the random-effect model is estimated inconsistently.

## 5. EMPIRICAL RESULTS

### 5.1. Unit Root Tests

The ADF and PP tests is used to check the stationary properties of the data time series, results may indicate that the variables are either I(1) or I(0). Initially, the test is done with all the variables at levels including a constant and deterministic time trend. The test statistic values are compared with the critical values on preferred significance levels. The results indicate that the calculated probability values of the variables are below the critical values at 1%, 5% and 10% significance levels (Table 2). Hence the null hypothesis for the presence of unit root was accepted, moreover a second test is done with the first differential of all the variables. However, the p-values of their first differentials are all above the critical value at 5% significance, thereby rejecting the null hypothesis for unit root. Based on the results obtained, it validates that our variables are integrated of order one that is, I(1). In addition, the optimal lag length (p) is selected based on the Akaike or Schwarz information criterion of (Pesaran and Pesaran, 1997). The results of the combined stationarity test are presented in Table 2.

### 5.2. ARDL Bounds Test

The optimal lag length for ARDL bounds test was selected based on the Akaike information criterion (AIC) and Schwarz information criterion (SC), which proved the optimal lag length for the models to be one. To check the reliability of our models a series of diagnostic tests are done such as; serial correlation test, autoregressive conditional heteroskedasticity (ARCH), CUSUM and CUSUM SQ stability tests. All the models in this study, were built with an unrestricted intercept and no trend. The results of the ARDL bounds test are reported in Table 3, which reveals that cointegration exists when both $LnCO_2$ and LnGDP are dependent variables. The calculated F-statistic value of 5.554034 for the $LnCO_2$ dependent model is greater than upper bound I(1) at the 5% critical value of (Pesaran et al., 2001), thereby rejects the null hypothesis for no cointegration. Similarly, F-statistic value for the LnGDP dependent model is higher than upper bound I(1) 5% critical value which confirms the presence of a long-run relationship. On the contrary, the F-bounds test value 2.817985 for the LnElec dependent model is lower than upper bound value at 5% significance level and therefore accepts the null hypothesis for no cointegration.

**Table 2: Results for ADF and PP unit root test**

| Variables | ADF statistics | | PP statistics | |
|---|---|---|---|---|
| | Level | First difference | Level | First difference |
| lnELEC | −0.970001 | −5.632724 | −1.128898 | −5.632724 |
| lnGDP | −3.029780 | −5.469262 | −3.029780 | −5.457574 |
| $lnCO_2$ | −3.378224 | −6.931921 | −3.382683 | −9.286641 |
| Critical Values | | | | |
| 1% | −3.592462 | −3.596616 | −3.592462 | −3.596616 |
| 5% | −2.931404 | −−2.933158 | −2.931404 | −2.933158 |
| 10% | −2.603944 | −2.604867 | −2.603944 | −2.6041867 |

**Table 3: ARDL bounds test result**

| Models | F-stat | I (0)-I (1) Bounds % | | | Decision |
|---|---|---|---|---|---|
| | | 1% | 5% | 10% | |
| Model 1 | 2.817985 | 3.17-4.14 | 3.79-4.85 | 5.15-6.36 | No cointegration |
| Model 2 | 5.101782 | 3.17-4.14 | 3.79-4.85** | 5.15-6.36 | Cointegration |
| Model 3 | 5.554034 | 3.17-4.14 | 3.79-4.85** | 5.15-6.36 | Cointegration |

**5% significance level

**Table 4: Error correction term for $LnCO_2$ dependent model**

| Independent variables | Coefficients | Standard error | T-ratio | P-values |
|---|---|---|---|---|
| C | −0.0188 | 0.06556 | −0.2869 | 0.7758 |
| D ($lnCO_2$(-1)) | 0.6533 | 0.26067 | 2.50628 | 0.0167** |
| D (lnELEC(-1)) | 0.01917 | 0.8628 | 0.02221 | 0.9824 |
| D (lnGDP(-1)) | 0.51998 | 0.50956 | 1.02047 | 0.3141 |
| ECT (-1) | −1.0973 | 0.30879 | −3.5534 | 0.0011** |

***, ** and *Denotes significance at 1%, 5% and 10% respectively

**Table 5: Error correction term for LnGDP dependent model**

| Independent variables | Coefficients | Standard error | T-ratio | P-values |
|---|---|---|---|---|
| C | −0.0065 | 0.02537 | −0.2543 | 0.8007 |
| D (lnGDP(-1)) | 1.05556 | 0.32982 | 3.20041 | 0.0028** |
| D (lnELEC(-1)) | −0.0585 | 0.04418 | 1.14376 | 0.2601 |
| D ($lnCO_2$(-1)) | 0.05053 | 0.267 | −0.2193 | 0.8277 |
| ECT (-1) | −1.0755 | 0.37625 | −2.8584 | 0.0070** |

***, ** and *Denotes significance at 1%, 5% and 10% respectively

Based on the bounds test result, an error correction term (ECT) is introduced in the LnGDP and $LnCO_2$ dependent models to extract their respective short-run and long-run elasticity. Tables 4 and 5 respectively shows the results of the short-run coefficients and ECT which are statistically significant and have a negative sign.

The coefficients of LnGDP and $LnCO_2$ as independent variables in the ECT models estimated above are respectively positive, which demonstrates the existence of a relationship between economic growth and carbon emissions for Cameroon. In order to have a more realistic view of the effect of recent economic growth on environmental quality, an EKC hypothesis is tested. Results of the EKC estimates are expressed in Table 6.

To check the validity of our EKC model, a structural stability test is conducted following the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of recursive residuals of squares (CUSUMSQ) test proposed by (Pesaran and Pesaran, 1997). From the results presented on Table 7, the coefficient values of lnGDP and $\ln(GDP)^2$ are statistically significant at the 10% critical value. Furthermore, the value of $\ln(GDP)^2$ has a negative sign which proves existence of an EKC hypothesis and the calculated threshold (t) value is around USD1056.18 (2010 constant prices). The threshold (t) value, here describes the point where the economy experiences the highest level of carbon emissions. Subsequently $\beta_1>0$ and $\beta_2<0$, this confirms the presence of an inverted U-shape curve as seen in the Figure 3 below for the carbon emissions and economic growth relationship in Cameroon during the period 1971-2014.

**Table 6: Results of EKC hypothesis**

| Independent variables | Coefficients | Standard Error | T-ratio | P-values |
|---|---|---|---|---|
| C | −18.933 | 8.17944 | −2.3148 | 0.0257 |
| lnGDP | 5.08569 | 2.58119 | 1.97029 | 0.0556** |
| ln $(GDP)^2$ | −0.3652 | 0.20253 | −1.8033 | 0.0787** |

**Denotes significance at the 10% level

**Table 7: Descriptive statistics of the carbon emissions-GDP relationship**

| Statistics | $CO_2$ | GDP |
|---|---|---|
| Mean | 0.29301 | 871.717 |
| Median | 0.23157 | 809.671 |
| Standard deviation | 0.16314 | 352.083 |
| Skewness | 1.36779 | −0.035261 |
| Kurtosis | 3.90695 | 2.46791 |
| Jacque-bera | 15.2276 | 0.52818 |
| Probability | 0.00049 | 0.76791 |

**Table 8: Results of Toda Yamamoto Granger non-causality test**

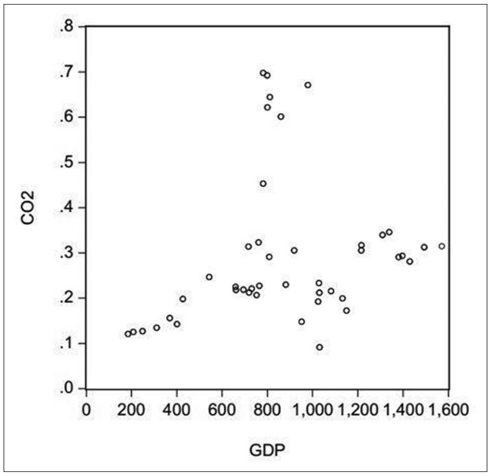
| Dependent variable | Independent variable | d.f. | P-value | Decision |
|---|---|---|---|---|
| lnELEC (Eq. 6) | lnGDP | 6 | 0.264 | Accept |
| | $lnCO_2$ | 6 | 0.4639 | Accept |
| lnGDP (Eq. 7) | lnELEC | 6 | 0.4148 | Accept |
| | $lnCO_2$ | 6 | 0.0023*** | Reject |
| $lnCO_2$ (Eq. 8) | lnELEC | 6 | 0.4243 | Accept |
| | lnGDP | 6 | 0.1956 | Accept |

***Denote rejection of null hypothesis at 1% significance level

### 5.3. Toda and Yamamoto Causality Approach

The variables could then be tested for causality, since integration of order one is confirmed and the existence of cointegration is proven in two models. Prior to causality test, a VAR model in levels is built to determine an optimal lag length (k) and after reviewing the AIC an optimal lag length of 6 is selected. Subsequently, an augmented VAR is estimated as $k + d_{max}$ where the maximal order of integration ($d_{max} = 1$) and the optimal lag length ($k = 2$). Results of the Toda and Yamamoto causality test is displayed in Table 8, the P = 0.2640 and 0.4639 obtained from Eqn. 6 are >0.05% significance level. Therefore, no causal relationship exists either from electricity consumption to economic growth or from economic growth to electricity consumption in Eqn. 7 and this result is coherent with findings from (Wandji, 2013) and (Tamba et al., 2017). Likewise, a neutrality hypothesis holds for the between electricity consumption to carbon emissions (in Eqn. 6) and vice-versa (in Eqn. 8). Alternatively, a unidirectional causality is confirmed in Eqn. 7 from economic growth to carbon emissions with a P = 0.0023 which is <0.05% significant level. This result

**Figure 3:** Scatter plot of carbon emissions versus economic growth for Cameroon




confirms the positive values and statistical significance of the coefficients of LnGDP and $LnCO_2$ in the error correction term.

## 6. CONCLUSION AND POLICY IMPLICATION

This paper attempts an analysis of the current situation of electricity consumption in Cameroon, its impediment on the country`s economy and further elucidates the effect the usage of carbon emitting fuels to generate electricity has on the environment. Despite the series of challenges plaguing Cameroon`s energy sector, the country stands out with the largest economy, population and highest electrification rate within the CEMAC region, it therefore plays a strategic role in sustaining growth in this sub region.

Empirical results shows existence of a unidirectional causality from economic growth to carbon emissions during the period under study. Though Cameroon is not a huge polluter with 0.26t $CO_2$ emitted per capita in 2016 (IEA, 2018), the results indicate that the country`s economic growth favors an increase in carbon emissions due to the generation of electricity from fossil fuel sources. The following factors may explain this situation; firstly the low rate of electrification in major regions of the country notably in the rural and remote areas has contributed to the dependence by the population on diesel oil generators to electrify their homes and do petty business. And finally though the country has an acceptable electricity access rate, there is a continuous increase in demand of energy due to rapid population growth and the existing old electricity production infrastructure hinders adequate distribution of electric power. The government has as main goal to become a developed country by 2035, in order to attain this objective it has to provide electrical energy to industries and households. Due to low supply of electric power, persistent power cuts and shutdowns, most industries in the country require the use of back-up thermal or diesel generators to sustain their activities. Simultaneously, the unidirectional causality existing between economic growth and carbon emission is consistent with the result of EKC hypothesis done in this study. The coefficients from EKC hypothesis is negative and statistically significant at 10% critical level, it confirms a direct correlation between economic output rise and increase in carbon emissions. However, the absence of causality relationship between electricity consumption and carbon emissions for Cameroon implies that in the present energy mix emissions produced as result of electric power consumption are negligible.

Despite the use of thermal or diesel fuel generators as back-up during electricity failures, 74.99% of electricity generated in the country is from less polluting hydroelectric sources. Nevertheless, a neutrality hypothesis holds between electricity consumption and economic growth for Cameroon. This result is similar to Tamba et al. (2017), who utilized a different approach based on vector autoregressive (VAR) model and Granger causality test. The present result of our research, indicates that electricity consumption has no effect on the economy, this situation is favored by the existing poor and ageing electrical network infrastructure in Cameroon. As a response to ameliorate the crisis facing the energy sector especially during peak periods, the government has envisaged to embark on the construction of a series of hydropower stations such as; Nachtigal 420MW, Memve`ele 200MW, Song Mbengue 950MW, Nyamzom 375MW, Bini Warak 50MW, Song Dong 250MW… to interconnect the national grid and further integrate the grid network with those of neighboring countries.

Therefore, it is primordial for the government to strengthen the energy sector by enacting power policies and regulations which will create an enabling environment for the production, distribution and sale of electricity. The national electricity corporation should focus on modernizing and expanding the ageing Southern, Eastern and Northern Interconnected Grid networks to reduce the rate of persistent power outages. The rural electrification rate in Cameroon is still less than 20% which is very low as compared to the country`s objective of attaining 48% by 2035. Therefore, it is essential to promote technological innovation and the generation of electrical power through renewable energy sources especially; solar and biomass, which are available and easily accessible to the local inhabitants. In addition, privileged should be given to building gas power plants which are less polluting as compared to diesel power stations. As a signatory member of the Paris COP21 agreement of the United Nations Framework Convention on Climate Change to reduce global GHG emissions, the government energy policies should seek to promote its clean energy sector by developing standard models which mitigate risks for investors and independent power producers. Environmental pollution data on Cameroon is still very scanty, the percentage of carbon emissions attributable to the use of diesel oil generators to produce electricity is actually not determined. Therefore, future works should focus on considering emissions from different electric power generation sources and hence provide comprehensive results on the pollution rate in the country.

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