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To Analyze the Casual Effect of Economic Growth, Energy Use on Fossil Fuel Consumption in Sub Saharan Africa with Structural Breaks

Ssali MW[*1#], Du J[1], Hongo DO[2#], Nderitu CW[3] and Nyaranga MS[1]

[1]School of Management, Jiangsu University, Zhenjiang, PR China
[2]Department of Statistics, School of Statistics, Jiangsu University, PR China
[3]Department of Applied Economics, School of Finance and Economics, Jiangsu University, PR China
[#]Ssali MW and Hongo DO has contributed equally

[*]**Corresponding author:** Ssali MW, School of Management, Jiangsu University, Zhenjiang 212013, PR China, Tel: +861889665291, E-mail: leadershipforimpact@gmail.com

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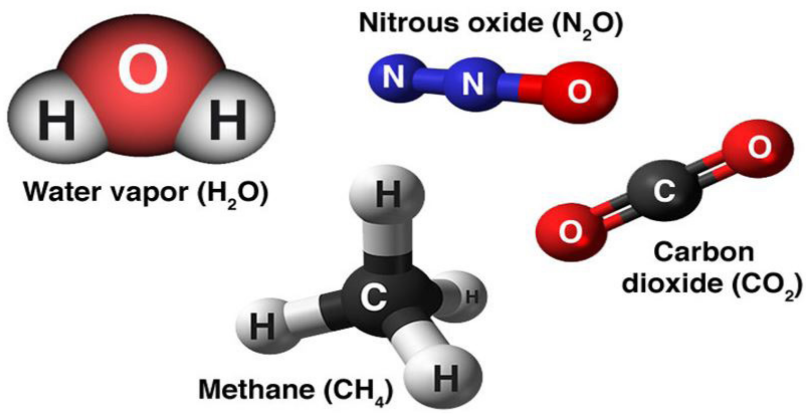
Abstract

The study seeks to investigate the casual effect of the efficient energy use and GDP (economic growth) on fossil fuel consumption (Nonrenewable) for the sub Saharan Africa for the period 1980 to 2014. The study also seeks to investigate solutions to environmental issues. Zivot-Andrews unit root test with a structural break, Phillips and Perron unit root test with structural break revealed that the investigated variables become stationary at first-differences. The Gregory-Hansen cointegration test with a structural break shows efficient energy use, economic growth and energy consumption are co-integrated. The long-run estimates obtained from the VECM model indicate that in account of the changes in the structure of the economies, the environmental Kuznets curve does not exist due to validity of a *U* shaped curve. An increase in output growth (GDP) and efficient energy use positively affect environmental pollution. Based on the findings of this study, the study recommends investment in green technology as the economy growths.

Keywords: Energy Use; Economic Growth; Fossil Fuel Consumption; Carbon Emissions; EKC; Structural Breaks; VECM; Health

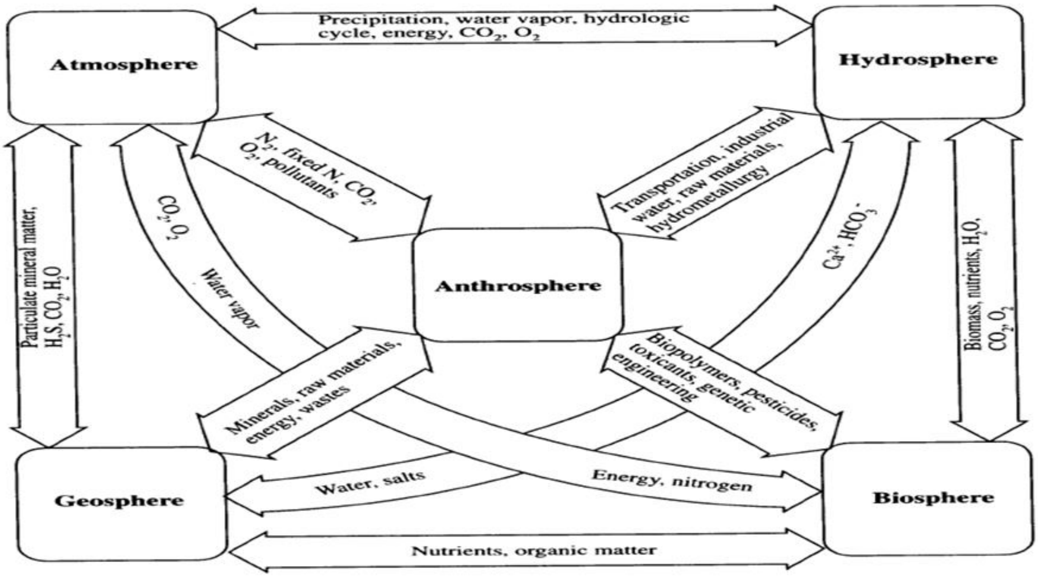
Introduction

Globalization and industrialization have turned the world into a global village motivated by energy and for economic enhancement. Energy and urbanization have been the main contributors to the global economic development. However, the demand for energy and increasing population have contributed to the depletion of energy resources like solid and liquid energy which have led to environmental degradation.



Source: NASA [3]
Figure 1: Greenhouse Gases

To a larger extent, environmental degradation has contributed a lot to Global warming and climate change. Recently, Global warming and climate change predominantly because of carbon emissions alongside its deadly results on eco system, global health, and economic activities, became a serious global matter of interest. As global warming and climate change continue to a be topic of discussion internationally, it is revealed by, that when gases like Water vapor (H_2O), Carbon dioxide (CO_2), Methane, Nitrous oxide, Chlorofluorocarbons (CFCs) hydrofluorocarbons, perfluorocarbons and Sulphur hexafluoride get into the atmosphere, they block the heat from escaping which makes these gases to stay permanently in the space because they cannot respond to the changes in the atmosphere physically or biologically causing climate change [1-3]. Eventually water vapor gases which do respond to the changes physically or chemically are observed as feedback [3] (Figure 1).



Source: Manahan S [4]

Figure 2: The divisions of Environmental science and how it's affected by the Greenhouse gasses

Manahan S, States that environment is comprised air, water, earth, life and technology which is strongly interconnected as illustrated in Figure 2. Manahan goes ahead to explain how these gases contribute to the degradation of the environment [4]. Reiterated that huge human utilization of energy resulted into a lot of environmental complications which have affected mankind that 90% of energy apprehended by photosynthesis and utilized as biomass for instance energy for welfare, wood for heating to the use of fossil fuel gasoline, natural gas, and coal, and 5% of the nuclear power, is for commercialization which have contributed greatly to carbon emissions.

According to the, its revealed that majority of the CO_2 emissions originates from the combustion of nonrenewable (fossil fuels) energy which have increased progressively ever since industrial revolution mainly from countries like China, USA, Russia and some parts of European Union [5]. Figure 3 below, indicates that the level of carbon emissions keeps on increasing and the prediction is that by 2030, the level of carbon emissions globally will increase to 38,000,000,000 Metric tons if nothing is done about it.

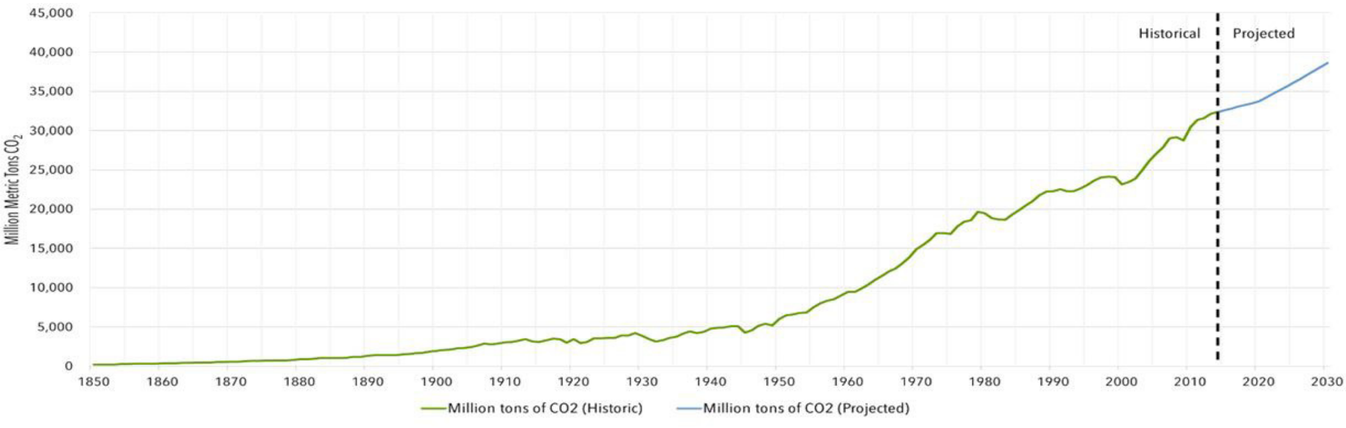


Figure 3: Global Carbon Dioxide Emissions between 1850-2030 [5,6]

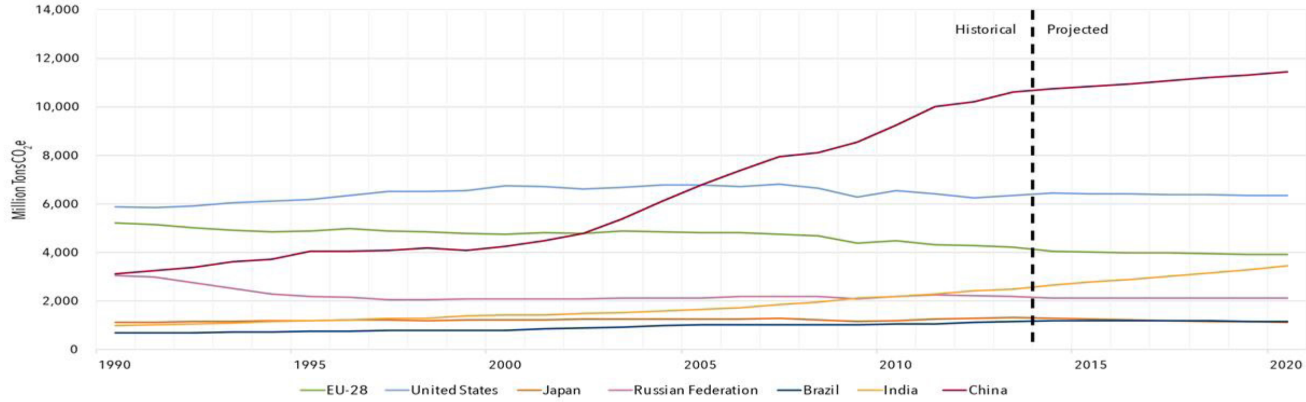


Figure 4: Greenhouse Gas Emissions for Major Economies, 1990-2020 [5]

The challenge of carbon emissions is still a threat to the whole world. That China is the leading carbon emitter in the whole world expected to emit 11,000,000,000 Metric tons by 2020 (Carbon Dioxide Information Analysis Center, 2017) (Figure 4). United States is in the second position expected to produce 9,000,000,000 Metric tons of Carbon emissions by 2020; followed by European Union, India, Russia, Japan and the Brazil. In 2017, carbon emissions increased by 1.6% which rebounded from the stationary capacity during 2014 to 2016. This has made China and India to be considered as the largest contributors to carbon emissions according to BP Global [7]. According to Olivier, Schure 26% of carbon emissions was by China, 7% by India and 3% by Japan in 2016 [8]. They also found out that European Union and United States are the absolute net importers of CO_2 while China and India are the main net exporters. It has been reported that global greenhouse gas emissions is on increase according to [9].

Some researchers revealed that several sources contribute to carbon emissions. The study done by Kofi Adom, Bekoe, stated that social development, economic development and industrialization have contributed greatly to the increase of carbon emission [10]. Another study by Heede R, Sanglimsuwan K, reported that greenhouse gases are emitted through burning of trash, burning of fossil oil, clearing of land for agriculture and during the production of cement and construction as a result of human activities [11,12]. Zhu Q, and X Peng Reported that greenhouse gases have been influenced by factors like population, industrial and agricultural production, consumption behavior, innovation-technology and infrastructural selections [13]. In sub Saharan Africa, Amegah and Agyei-Mensah, stated that population growth increased ownership of vehicle, use of solid fuels for domestic use, Industrial expansion are major contributors to environmental pollution [14].

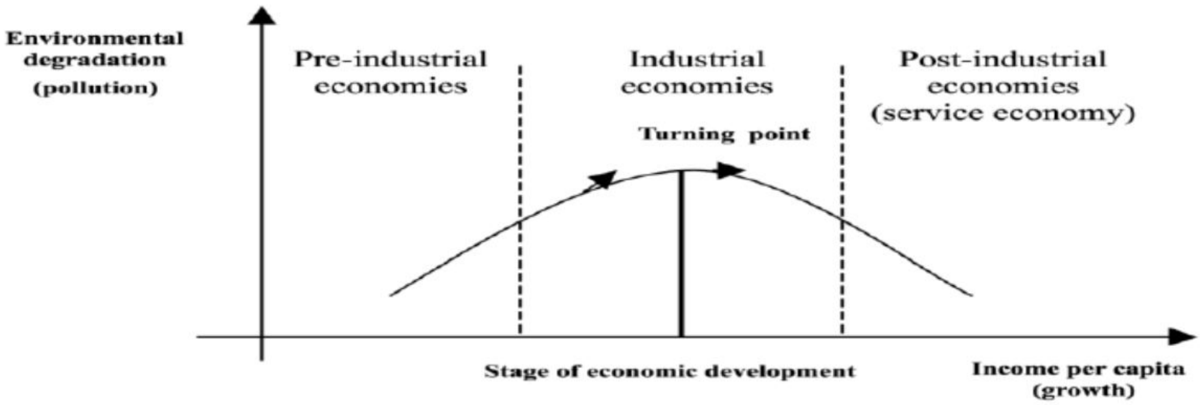
Based on the research by IPCC, it was revealed that from 2000 to 2010, 78% of the total greenhouse emissions were from fossil energy consumption, industrial and agricultural activities [15]. Affirmed that the use of fossil fuel such as natural gas, gasoline and coal has been considered to be one of leading emitter of carbon emission in the world today that the world is facing climate change and global warming because of fossil fuel which causes greenhouse gases in the atmosphere these gases stay in the atmosphere for about 100 years. As per the United States Environmental Protection Agency, stated that overall GHG outflows from human exercises expanded by 35% from 1990-2010. Most of the world's emanations in 2011 outcome from the utilization of energy (83%), which is trailed by agriculture (8%), industrial methods not connected to energy (6%), and waste (3%) [16]. Owusu PA and Sarkodie SA also confirmed by stating that the demand for fossil fuel for production, electricity for domestic use, health issues and for sustainable economic development has constantly increased which has encouraged over dependence on nonrenewable energy [17]. Reiterated that the eagerness for energy use grows everyday due to the increasing income of developing countries and at the same time, the population is also increasing; that by 2040 the population is expected to increase to 9 billion which will affect the energy mix because of the advancement in technology. As the population increases, the demand for energy has also increases [18]. Manahan S, Lee CT, Hamilton TGA, Kelly S, These researchers also suggested that the best way to deal with this challenge of global warming is by practicing low carbon [4,19,20]. Globally, the environmental impact of greenhouse gases have become of great importance and of interest [21]. Carbon dioxide alone contributes to a huge percentage of the greenhouse gases which have resulted into universal warming and climate change [22].

World Health Organization under UN environement openly stated that air pollution is the greatest silent killer than Tuberculosis, HIV and Malaria all put together [23]. That air pollution includes smoke from traditional cooking (use of fire woods), mining industries, manufacturing industries which cause diseases like cancer, asthma, gastrointestinal, immunological, cardiovascular and neurological damage. They also reiterated that out of 7 deaths, one is as a result of environmental pollution. 94% of these deaths happen in developing nations. Based to the research done by several researchers, it is reported that Nitrogen is noxious and can generate aggravation of the eyes and throat, snugness of the chest, sickness, cerebral pain, and continuous loss of strength [24-26]. Exposure to NO_2 for a longer period of time it can cause fierce hacking, trouble in breathing, and cyanosis; it can be considered as a lethal weapon toward the environmental and humanity [27]. NO_2 is a ruddy dark colored, exceedingly responsive gas that has a stifling scent and is a solid oxidizing operator [26]. It is exceedingly lethal and unsafe in view of its capacity to cause deferred substance pneumonitis and aspiratory edema. NO_2 vapors are a solid aggravation to the aspiratory tract [28,29]. The broad effects of noxious gases on environmental change and related impacts on water-carbon parts have been perceived, going from evapotranspiration and spillover to net biological community efficiency and gross environment exchange [30]. For example Acid rain with of nitric and sulfuric acids are framed fundamentally by Nitrogen Oxides and sulfur oxides released into the air when petroleum products are flamed according to Partrick LD, Sullivan RK, Murry TP, Kampa M and Castanas E [31,32]. Nitrogen Oxides and sulfur oxides released into the air when petroleum products are being consumed, they contribute to the evolution of lung tumor, ventricular hypertrophy, Alzheimer's and Parkinson's ailments, mental difficulties, extreme introvertedness, retinopathy, fetal development, and premature births [33].

These challenges of environmental degradation attracted many International bodies to get involved in the fight against environmental degradation which had become a threat to the environment and mankind. International bodies like United Nations Framework Convention on Climate Change (UNFCCC) organized several conferences to discuss strategies of dealing with this challenge of global warming. Corbeels, Cardinael, stated that the United Nations Framework Convention on Climate Change (UNFCCC) in 2015 during the Climate Agreement in France-Paris, encouraged nations to work toward the reduction of the global rising temperature to slow it down to at least below 2 °C to develop a more enthusiastic objective to constrain global warming to 1.5 °C [34]. During the 5^{th} accomplishment of IPCC nations agreed to zero down carbon emissions by 2020 [35]. In 2016, UNFCCC conference at Marrakech approved the blue print for the development of Paris agreement [36]. The Paris Climate Agreement and United Nations Sustainable Development Goals promised to stop the escalation of global warming, and stimulate sustainable economic development, mainly in the eco- energy area [37].

Materials and Methods

It's not that easy to identify the causal variables for both economic progression and the kind of the relationship between economic enhancement and environment [38]. It's a complex matter because both developed and developing nations don't use the same technologies with different impact on the environment in the long run. Hence, developing nations will experience intense carbon emissions than developed nation because of their technological advancement plus new innovations. The relationship between economic growth and environment proves the existence of EKC hypothesis which states that as the income increase, carbon emissions also increases and later it drops down when it reaches the turning point when there is income normalization to enable the introduction of environment friendly technologies to reduce on environmental degradation [39]. This means that as the result of the drop, there is an existence of inverted-U-shaped association between carbon emission as and economic growth (Figure 5).



Source: Panayotou T [40]
Figure 5: Environmental Kuznets Curve: The relationship between Economic Development and Environmental degradation

Most present studies investigated diverse mixtures of levels of relationships for diverse countries, diverse periods and methods used. Centered on the preceding, the conclusions continue to be indecisive, whereas policy recommendations are different. The interesting thing is that most of the literature in these particular areas proposed the presence of causality hypothesis like neutrality, feedback, growth and discussion have got conflicting results through the regions and countries as well [41-43]. In addition, there are some studies which have conducted research on the EKC in the process of examining the linkages.

Other researchers have examined the causal relationship between carbon emissions as dependent variable together with multiple independent (explanatory) variables like economic growth, foreign direct investment, energy consumption, energy use, urbanization plus many more other variables [44,50-52]. The main indicators that have been used as environmental degrader proxies include carbon dioxide, Sulphur dioxide emissions and methane as a result of fossil fuel consumption. In this case fossil energy has been ranked to be the back bone of any emerging economy [52,53]. These erstwhile empirical studies reported that the existence of Granger causality as well as the direction of causality between GDP, renewable energy consumption and carbon emissions from fossil fuel can be determined by the nominated data, the considered time-period, and the applied econometric methodologies. However, the majority of these investigations are in agreement that the causality among the consumption of eco energy and economic development and the positive impact of eco energies on both economic progression and the environment [54]. It's the energy consumption is the factor which is on high demand for economic development in both developing and developed nations.

Economic Growth and Fossil Fuel Consumption (Environmental Pollution)

Based on the introduction of this research, carbon emissions must be dealt with so that the quality of the environment is secured. The use of clean energy and the reduction of fossil fuel should be heavily encouraged. But again once there is cut on the consumption of fossil fuel energy, it is most likely to affect economic growth as well as national income. To avoid this effect of reduction in (Nonrenewable) fossil fuel consumption on the economy of nations, enough research has been conducted to provide sustainable policies which would not affect the economic growth and the national income. This challenge carbon emissions forced researchers to investigate the connection between fossil energy consumption and economic growth [55-58].

Applying different datasets and econometric methodologies, previous researchers have shown that the causality among fossil energy consumption and economic growth are capable of being unidirectional from one variable to another as well as bidirectional [59-61]. Old methods of research are not appropriate to find solutions to present challenges. Some studies have applied structural break in identifying the relationship between energy consumption and economic growth [62,63]. In most studies, before testing for causality, employment of the Zivot and Andrews unit root to have access to structural break and structural change by Phillips and Perron test was conducted to detect unpredictability challenges [64,65]. Other methodologies like bootstrap rolling window Granger causality test by, the dummy test for dummy variables, the Markov switching vector auto regressions which are also utilized to explicate for structural change [66-68]. Researchers like Lee CC, Chiu YB, Arouri, Narayan PK and Smyth R, Apergis N, Payne JE amongst other researchers, have exerted panel co-integration methodologies alongside multiple structural breaks and panel data unit root tests alongside structural breaks to discourse the energy-growth propaganda [69-72]. For example explored the causal correlation amid non-renewable electricity, carbon emissions, economic growth, consumption and renewable electricity consumption in Algeria [73]. Using Autoregressive Distributed Lag Co integration method over the period 1980–2012, the results indicated that among the variables cointegration long-run relationship exists. Based on their study they found that, economic growth and fossil electricity consumption affects the quality of the environment in the long-run while renewable energy use reduces environmental degradation. In the short run, findings report that unidirectional causality connection flows from GDP to non-renewable electricity consumption, which proves the conservation hypothesis, implying that electricity consumption is determined by economic growth. They concluded by positing that renewable electricity consumption has the capacity to enhance environmental quality in Algeria.

Guan D, *et al.* evaluated the drivers responsible for the increase and decrease of carbon emissions in China between 2007 and 2016 [74]. Using the newest present data of energy, economic and industry they found that slow economic growth led to the reduction of carbon emissions in China. However, according to their results, the change in industrial structure led to the reduction of carbon emission in China. When they applied econometric method, the results revealed that there is a clear structural break around 2015 in the carbon emissions of China.

Economic growth is an extension in the production of goods and services execution over a specific period. To be correct, the estimation must oust the effects of inflation. Economic growth or development makes more advantage for organizations and a nation in general. Hence, stock costs rise gives firms resources to remain in business. They contribute and contract more laborers and as greater work opportunities are made accessible as well as compensation rise. Be that as it may, as much as nations would need to see their income enhances, this comes with consequences like carbon emissions. This makes it's very important to understand the nexus between this economic growth and carbon emissions. According to Han, Du, revealed that it's imperative to have a decent comprehension about the relationship between environmental pollution and economic growth to disclose the interfaces between human activities and the natural ecology to reduce greenhouse gases [75].

The nexus between environmental defilement and economic growth can be shown by EKC (Environmental Kuznets Curve) presented by Simon Kuznets in 60s. He revealed that environmental contamination rises correspondently as one with economic growth. That when there is an increase in the income level and when the income ascends to a particular level, at the defining moment CO_2 begins to decrease. Accordingly, an inverted U-shaped between environmental defilement and economic growth is made. Ahmed and Azam, they exhibited that the current literature displays the connection between energy usage and economic progression is extensively examined [45]. However, the experimental discoveries are yet not made clear and irreconcilable with respect to the trend of causality. Basing on their research using cross-countrytime-series unidirectional causality runs from (GNP) Gross National Product to energy utilization, for both Chile and Argentina. Another study by Özokcu and Özdemir, investigated the relationship amongst income and Carbon emissions in regard with the Environmental Kuznets Curve (EKC) and the affiliation among income, energy use, and CO_2 emissions for the period of 1980 and 2010 [76]. They used Driscoll-Kraay Standard Errors. Based on their outcomes showed that N-shape and an inverted N-shape correlation are witnessed; which imply that EKC hypothesis is not supported by the findings. This means that economic growth cannot obviously mitigate environmental degradation.

Using the threshold co-integration tests, explored the long term affiliation of stock prices of different energy firms with oil prices [77]. Their findings indicated the presence of co-integration between the variables with two endogenous structural breaks. They stated that once the presence of structural breaks is ignored, will mislead researches when it comes to presenting results. Ssali MW, *et al.* examined the impact of GDP, efficient energy use and population on carbon emissions in sub Saharan Africa from 1990 to 2014 [78]. Using unit root test, cointegration test, Vector Error Correction Model (VECM) and Fully Modified Ordinary Least-Square (FMOLS), their findings revealed that efficient energy use increases carbon emissions and they suggested that governments should concentrate more on renewable energy to regulate the use of nonrenewable energy and promote renewable energy.

This should capture the attention of global leaders to sustainably deal with this challenge of greenhouse gases. As the standards of living increase, the probability of greenhouse gases to increase and the decrease of natural resources are inevitable. There has been a complexity between economic enhancement and energy consumption. But even if there is that complexity between the two variables, the need for energy is very important for any economy to grow.

Efficient Energy use and Fossil Fuel Consumption (Environmental Pollution)

Wu J, *et al.* stated that industries in China have expanded massively ever since the introduction of “reform and opening-up” policy in 1978 [79]. But ever since the implementation of this policy, there has been huge consumption of energy and increase in environmental pollution attracting the attention of the government authorities. They conducted a study to investigate the reasons to why energy consumption and environmental pollution kept on increasing. They evaluated the Total-factor energy efficiency industries in China. When they exerted two-stage DEA model with shared inputs, their findings revealed that between 2006 and 2010, there was an improvement in the performance of the industries in China and that is when efficient energy use increased and it was more greater than the stages of environmental pollution management.

Wang S, G Li, C Fang explored the relationship between urbanization, economic development, energy consumption, and CO_2 emissions. Using a series of panel data models of 170 countries for the period of 1980–2011 [80]. Their findings of panel co-integration tests revealed the existence of co-integration relationship among the variables in the countries investigated. They also revealed that there is an existence of significant positive relationship among the variables used in the long run. The results of Vector Error-Correction Model (VECM) supported the presence of diverse Granger causality correlation between the variables. Their findings revealed a new insight on the value of a country's growing stage and the level of income to support policymaking relating to the mitigation of carbon emissions.

In Tunisia, Ben Jebli and Belloumi exerted (ARDL) method and Granger causality tests and their results reported that a bidirectional short-run causality amid sea transport and CO_2 transmissions and a unidirectional short run causality following from waste depletion real, GDP, railroad transport and nonrenewable to CO_2 radiations [81]. The long-run estimations revealed that real (GDP) induces the abatement of CO_2 emissions, while waste depletion, nonrenewable, railroad transport and sea positively encourages emissions. The study by Alshehry and Belloumi Alshehry AS, M Belloumi presented that the causal link between energy utilization, energy cost and economic exercises in Saudi Arabia [82]. Their study exhibited a long-run unidirectional causality from energy consumption to financial development and environmental pollution. They also revealed bidirectional causality among carbon dioxide emissions and financial development. The long run unidirectional causality flows from energy cost to economic growth and environmental pollution, and a short-run, unidirectional causality flowing from carbon emissions to efficient energy use and monetary yield and from energy cost to carbon emissions.

The estimation of trade and energy use nexus by Topcu M, JE Payne, in OECD nations for over the period of 1990–2015 by the use of panel structure and cross-sectional dependence, revealed that the influence of trade on efficient energy use showed an inverted U-shaped pattern which exhibited that there is more impact of carbon emission on efficient energy use as compared to economic growth [83]. Behera SR, DP Dash, scrutinized the relationship between energy consumption, foreign direct investment (FDI), urbanization and carbon emissions in South and Southeast Asian (SSEA) area the period of 1980–2012 [84]. Using Pedronico-integration their results reported that both the primary energy consumption and fossil fuel energy consumption do increase carbon emission in the SSEA province.

Heidari H, ST Katircioğlu, and L. Saeidpour, used the panel smooth transition regression (PSTR) model to examine the connection between economic growth, environmental pollution and energy consumption in five ASEAN [85]. Their study showed that energy consumption increase CO_2. In the G-7 countries Balcilar, Ozdemir, scrutinized the correlation amongst energy consumption, economic growth and carbon dioxide emissions [86]. They exerted historical decomposition method and their report indicated that United States, Canada, Italy and Japan needed to reduce on most of their economic dealings to diminish CO_2 emissions. Mirza FM, A Kanwal studied the existence of causality among energy consumption, economic growth, consumption and environmental pollution for Pakistan [87]. They used ARDL to examine the robustness of the long-run connection. They also used VECM to test for the existence of Granger causalities. They reported that there is bidirectional causalities among variables. As per their results, they proposed that renewable energy should be increased by the Pakistan government.

When Ahmad M, *et al.* exerted ARDL model to explore the impact of total population, economic growth and energy consumption on carbon emissions in China for the period of 1971 to 2013, They identified a relationship amid economic growth and carbon emissions which inveterate the existence of long run correlation. When they used Granger causality test, their study revealed the existence of one-way causality among economic growth and carbon emissions [88]. Their final findings divulged that efficient energy use and economic growth have got great potential to induce carbon production in the long run. Their suggestion was that governments affected by carbon emissions should focus on the promotion of sustainable energy for sustainable economic development and living for their citizens. Solarin SA, *et al.* investigated the pollution haven hypothesis in Ghana considering (GDP), GDP^2, energy consumption, renewable energy consumption, foil fuel energy consumption, foreign direct, institutional quality, urbanization and trade openness as its main determinants for the period of 1980-2012 [89]. They used auto-regressive distributed lag (ARDL) and structural break methods. Their findings revealed co-integration which shows that among the variables, long run relationship existed. On the other hand, international trade, GDP, urban population, FDI, financial development and have a statistically significant positive impact on carbon emissions, whereas institutional quality declines carbon emissions in Ghana. As reported by Li and Tao, efficient energy use plays a huge part in socio-economic activities as it encourages the preservation of the global environment [90]. Another study by Long, Naminse, investigated the relationship among renewable energy, carbon emissions and economic growth in China from 1952 to 2012 [91]. Their study indicated that coal has a great prevailing impact on the growth of the economy and carbon emissions. While oil use has got a great positive impact on carbon emissions. Because of the results, their recommendation is that there should be change in the structure of coal consumption to encourage the reduction of carbon emissions.

Since nations are attacked by unanticipated shocks (structural change) in economic growth, efficient energy use and fossil fuel consumption, any employment of econometric methodologies without considering structural break may create room for wrong results or errors as reported by [63,92]. Due to the gaps in the literature, the study analyzed the casual effect of economic growth, efficient energy use on (Nonrenewable) fossil fuel consumption by employing Phillips and Perron unit root test with structural break and the Zivot and Andrews unit root test with structural break as well structural change, co-integration test by Johansen and Juselius, VECM and Granger causality test by Granger CW. The study will also investigate the possible solutions to Greenhouse gases in sub Saharan Africa and the world at large [64,65,93-95].

Methodology

The study seeks to investigate the casual effect of the energy use (efficient energy use) and GDP (economic growth) on (Nonrenewable) fossil fuel consumption for the sub Saharan Africa for the period 1980 to 2014. We used data from World Development Indicator (WDI) from 1980 to 2017. In the process of economic development, especially in the pre-industrial phase where energy consumption and other inputs of production, fossil fuels forms the main energy source especially for majority sub-Saharan states. Intuitively consumption of such non-renewable energy source like coal and petroleum products result to the emanation of greenhouse gases as by product into the atmosphere. In our study, we utilize (Nonrenewable) fossil fuel consumption as a proxy to environmental pollution and investigates its effect using the environmental Kuznets curve context in the account of structural breaks. If we let gross domestic product, fossil fuel consumption and energy use represented by GDP_t, Ff_t and Eu_t with time variable as t, the Table 1 below tabulates their descriptive statistics

	$\ln Ff_t$	$\ln GDP_t$	$\ln Eu_t$
Mean	1.599176	2.812035	6.524655
Maximum	1.635609	3.260162	6.583444
Minimum	1.558799	2.346474	6.475557
Std. Dev.	0.019445	0.213283	0.02843
Skewness	0.260959	0.492779	0.615282
Kurtosis	2.674555	3.221883	2.569632
Jarque-Bera	0.693574	1.871023	3.115759
Probability	0.706956	0.392385	0.210582
Observations	44	44	44

Table 1: Descriptive Statistics

In the EKC context, it is hypothetical as the level of the wealth increases, the state channel more resources towards environmental preservation and at the same time creates awareness about the dangers of environmental degradation. In the process, the economy will improve as the reduction of carbon emissions takes place. In our study, we investigate these determinants using Equation and Equation in the EKC phenomena. e_t Denotes to a set of structural and institutional unobserved factors in the sub-Saharan economies that affect the quality of the environment

$$\ln Ff_t = c + \ln GDP_t + \ln Eu_t + e_t \quad (1)$$

$$\ln Ff_t = c + \ln GDP_t + \ln GDP_t^2 + \ln Eu_t + e_t \quad (2)$$

Empirical Results and Discussions

Unit Root test

Before carrying out cointegration test to investigate the long-run connection between economic growth, energy use on fossil fuel consumption, it was important to test the stationary of the factors by the use of unit-root test.

One of the major aims of using a unit root test is to find out if or not a time series data is stationary. In case there is no stationarity in the variables, this would affect the estimation procedure. To avoid any econometric problems in the process of estimation, Phillips and Perron (PP) and Zivot and Andrew (ZA) unit test was together with structural break were exerted [65,96]. The study selected lag lengths according to the Akaike Information Criteria (AIC). We executed the pre-conditions for modeling Equation (2) by testing the stationarity of our variables using the Phillips and Perron unit root test [65]. Since the time series plots of the variables in Equation (1) seems to perpetrate breaks in their structures, we also employed the unit root test which is sensitive to structural breaks compared to the serial correlation sensitive PP test [96]. The PP test follows the Dickey Fuller format of Equation (3) below. From the equation, y_t represent the time series to be diagnosed, y_{t-1} is the series' one time lag due to differencing operator $(\Delta)x_t$ -is the exogenous reggressor included in the test equation while ∂ and ℓ are the estimate parameters.

$$\Delta y_t = c + y_{t-1} + \partial t + D_{i,t}(\tau) + \sum_{i=1}^{k} \psi_i \Delta y_{t-1} + e_t \tag{3}$$

Under PP, we test Eqn (3) on the $H_0 : \partial = 0$ versus $H_0 : \partial \angle 0$ based on the trace statistics (t) in Equation (4) below.

$$t_{\partial} = t_{\partial}[\lambda_0 / \pi_0]^{-2} - [T(\lambda_0 - \pi_0)(se\hat{\partial}) / 2\pi_0{}^{-2} s_e] \tag{4}$$

Where t_{∂} and $\hat{\partial}$ are the t-ratios and estimates respectively. $S_e\,\hat{\partial}$ denotes the standard errors while S_e is the regression standard errors. $\pi_0 = (T-k)\,S^2 / T$ is the shock variance, k-the number of reggressor and $\hat{\lambda}_o$ - the estimator of the shock spectrum at zero frequency. The above t_{∂} statistics are robust to any autocorrelation in the series and we estimated t_{∂} at intercept *(c)* and at both intercept and trend (*C* & *t*). On the other hand, Esso LJ accorded social-economic, political and other institutional reforms in sub-Saharan countries coupled with some natural disasters like climatic changes likely to alter the stability of such economies [97]. The aftermath ensues through drastic shifts in the macro-economic series. Thus, we utilized the Zivot and Andrews's unit root test: Equation (5) did at trend shift, which supersede the traditional PP that produce distorted estimates due to structural breaks. From the equation, *l* denotes to binary break timing in the date so that it is a unit value for breakpoint and 0 otherwise. $DD_{i,t}$ is the dummy that traces the breaks in the trend. Table 2 column (2) and (3) reports PP and Zivotes' results

$$\Delta y_t = c + y_{t-1} + \partial t + DD_{i,t}(\tau) + \sum_{i=1}^{k} \psi_i \Delta y_{t-1} + e_t \tag{5}$$

PP			Zivote- Andrews		
t-Stats			break	Min^m t-stats	
	c	C & t	*lag*	date	*@ t*
ln Ff_t	-2.356	-2.305	0	1982	-3.182
Δ ln *Ff*	-6.862*	-7.089*	0	1991	-8.117*
ln GDP_t	-1.092	-1.790	1	2002	-4.569*
ln GDP_t	-3.845*	-3.792*	0	1983	-4.991*
ln Eu_t	-1.885	-2.022	0	1983	-2.337
Δ lnEu_t	-7.322*	-7.313*	0	1994	-8.005*

*significance @5%, Maxm lag chosen based on AIC

Table 2: Unit Root test

Cointegration Tests

We proceeded to model cointegration test to experiment whether the variables (GDP_t, Ff_t and Eu_t) are co-integrated. We used the Johansen and Juselius and Gregory and Hansen [93,98]. The major purpose of this cointegration test is to detect whether all variables flow together in the long run. The former constitutes the baseline cointegration test unlike the latter which accounts for the changes in the structure of the economy through breaks in the macroeconomic time-series. We run the former from a group structure of Equation (1) variables based on the null: the variables are not co-integrated when the maximum *t* statistics is used in Equation (4) below. In Equation (4), *y* and *l* refers to the sample size and n^{th} canonical correlation. We reported both *t* and $t - max^m$ statistics in Table 3.

$$t_{\max^m} = -y \ln(1 + l_{r+1}) \tag{6}$$

In the presence of time-series parameter change at unidentified date, Gregory and Hansen advancement that measure instability in the aforementioned difference stationary series is a depiction that the variables are co-integrated. In our case, we modeled all the 3 formats of GH: (1) at intercept, (2) at intercept and trend and (3) at intercept shift and slope as depicted by equations (6) and (8) respectively.

$$y_t = c + \partial D_t + \delta x_t + e_t \tag{7}$$

$$y_t = c + \partial D_t + \delta x_t + \vartheta X_t D_t + e_t \tag{8}$$

$$y_t = c + \partial D_t + \varphi t + \delta x_t + \vartheta X_t D_t + e_t \tag{9}$$

Herein, y_t and x_2 are scalar variables and $K \times 1$ vector of independent variables but all difference stationery. D_t denotes the break dummy as a fore mentioned, and t is the trend while c and ∂ represents intercept parameter before and after the break respectively. For equation (7) and (8), ϑ traces the change due to regime shifts in the co-integrating vector. These later equations denote a break in the trend and slope respectively, which is an addition to intercept shift. The right hand side columns in Table 3 tabulate the results of Equation 6 to 8.

	Johansen[a]		Gregory and Hansen[b]			
	statistics			ADF	z_t	Break date
rank (r)	*t*	*t-max[m]*	*@ i shift*	-6.41*	-6.41*	2000
r=0	113.7*	57.09*	*@ i shift-t*	-7.09*	-7.18*	1987
r=1	56.61*	47.44*	*@ i shift& s*	-9.30*	-9.31*	1987
R=2	9.169	9.053				

H_0*significance @1%, maximum lags is 1a and 2b respectively; H_0 no co-integration;
Optimal lag from built Var is 2 by FPE/HQIC/BIC/AIC
Table 3: Cointegration test

The co-integration post estimation we executed was based on the chances of rejecting the null in Equation 5-8 aiming at the elucidation of the co-integration and the long run relationship in the end. Vector error correction model (VECM) has been established to deal with this imperfection.

VECM

Vector error correction model (VECM) has been established to deal with this imperfection. VECMs organize a theory-driven methodology that is convenient for estimating short-term and long-term effects of one time series on another. So we developed VECMs because they are useful methodologies when handling co-integrated databases and stationary data. For example if variables y and z are time series that are connected in the long run, noticing that some detected variables are not always just on the equilibrium point, but fluctuation point [99]. We considered the series dynamic non-equilibrium procedures during the establishment of VECMs in order to identify the long term relationship among the variables. The VECM results are stipulated in the Table 4.

We therefore estimated equation (2) using a vector autoregressive cointegration model (VECM) done at both baseline and in account of structural breaks.

$$\Delta y_t = k + m_1 \sum_{i=1}^{L-1} \Delta y_{t-i} + m_2 \sum_{i=1}^{L} y_{t-i} + \vartheta ect_{t-1} + e_t \tag{10}$$

Where y_t refer to endogenous dependent variable, k, m_1 and m_2 the constants, short run and long run vector of parameters to be estimated respectively. ϑ is the adjustment speed to the long lasting equilibrium and expected to be negative while ect_{t-1} is the one time delay of the shock correcting term. Alongside the baseline equation, we also modeled the VECM accounting for structural breaks where we captured the time break dummies.

		Regime shift equation		**Baseline Equation**	
		Coefficient	t-stats	coefficient	t-stats
short run	k	0.248	0.42	-0.693	-0.84
	$\Delta \ln GDP_t$	0.374	0.134	0.426	0.69
	$\Delta \ln GDP_t^2$	-0.075	-1.49	-0.071	-0.65
	$\Delta \ln Eu_t$	-0.105	-2.02**	-0.142	-1.33
long-run					

	Regime shift equation			Baseline Equation	
	$\ln GDP_t$	-1.386	-2.40**	0.998	1.64
	$\ln GDP_t^2$	0.285	2.54**	-0.168	-1.65
	$\ln Eu_t$	0.427	2.90***	0.356	1.63
	dmy ln *GDP*	1.850	3.86***	-	-
	dmy ln *GDP*	-0.359	-3.95***	-	-
	dmy ln *Eu*	-0.791	-3.95***	-	-
	dmy ln *Ff*	1.731	2.84***	-	-
adj speed	$I \ln Ff_{t-1}$	-0.524	-2.93***	-0.316	-1.20
	likelihood = 184.6, $r^2 = 0.861$			likelihood = 0.053, $r^2 = 0.211$	

Table 4: VECM

Granger Causality Tests

Granger causality tests are globally exerted to investigate, examine causal relationships among variables. It's a statistical hypothesis test used to find out if one variable affects another variable for determining whether one variable affects another. So we developed the basic granger causality to guide delimitate the direction of causality among economic output (the GDP), efficient energy use and the fossil fuel consumption. For that matter, we explicated the Granger CW which embodies the ordinary least square regression estimators of reggressor series to predict another series [95]. The format traces Equation (10) below

$$y_t = k + m_1 \sum_{i=1}^{L} y_{t-1} x_{t-i} + e_t \qquad (11)$$

Where y_t and x_t are I (1) vector of endogenous variables and x_t is said to cause y_t if m_2 are all jointly significant and vice. The causality is bidirectional if x_t and y_t causes each other. Table 5 bears the results of granger causality.

	$\ln GDP_t$	$\ln GDP_t^2$	$\ln Eu_t$	$\ln Ff_t$	To all
$\ln GDP_t$	-	0.348	0.701	0.530	0.010**
$\ln GDP_t^2$	0.115	-	0.576	0.643	10.23**
$\ln Eu_t$	32.27***	31.79***	-	83.61***	84.28***
$\ln Ff_t$	1.323	1.321	1.674	-	2.1164

and*significance @5 and 1%, numbers denotes x^2-statistics

Table 5: Granger Causality Test

We used Granger causality test to explore whether one-time series is vital in forecasting another one-time series based [95]. In table 5, the causality output, output squared and efficient energy use to all other variables is significant at 5% except for fossil fuel consumption. On the other hand, efficient energy use is the main determinant to environmental pollution, economic growth and (Nonrenewable) fossil fuel consumption thus the need for the country block under study to adopt environmental friendly sources of energy. In comparison, the regime model better explain for degradation of environment at 86.1% unlike 21.1% with the baseline model. With respect to prediction, the former better predicts the situation than the baseline due to its higher likelihood value. From their Cusum plots both model estimated parameters are stable at 5%.

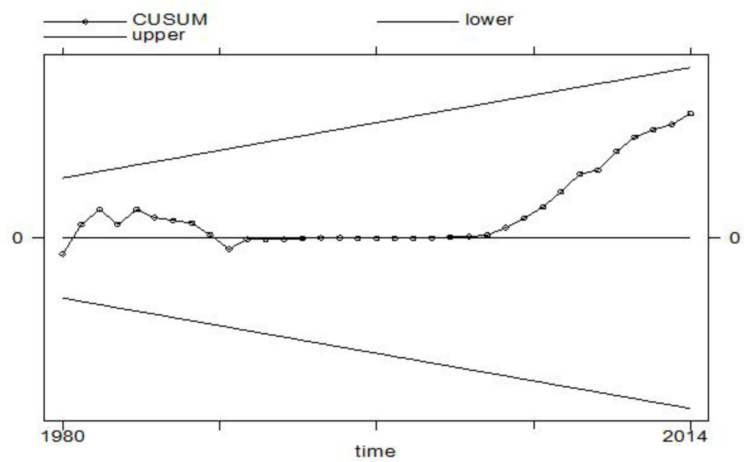


Figure 6: CUSUM

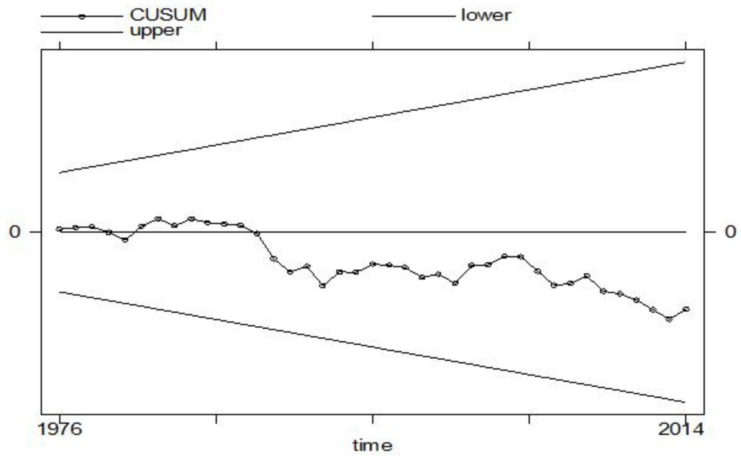


Figure 7: CUSUM

We also executed the Cusum test and run diagnostic investigations to contrast the performance of the two models in Table 4. Figure 6 and 7 bears the Cusum test [100]. Majority of studies use the stability tests to expose the stability of the estimated method and the stability of both the long and the short run coefficients [101].

In accordance to table 1 we described the measures of dispersion and central tendencies of, $ln\ Ff_t$, ln Eu_t and ln GDP_t. Each variable had 44 observations. Efficient energy use is the most predominant and widely utilized variable with a mean of 6.524 and standard deviation 0.0284 in comparison to ln GDP_t and ln Ff_t. The less positively skewed values and the less than 5 kurtosis statistics depicts to a relatively well spread data with minimal outliers. Hence the statistically insignificant JB statistics subscribing to a normally distributed series. Our variables intuitively fit macro-economic pre-estimation like unit root diagnostics displayed in Table 2.

Both Phillips and Perron of traditional root test and the Zivot and Andrews from Table 2 were done to investigate the null hypothesis of unit root absence under serial autocorrelation condition by the former and absent under regime change conditions in the time series by the later. Both the $t - stats$ and $Min^m\ t - stats$ confirms that at level, ln Ff_t, ln Eu_t and ln GDP_t propagates a unit root but after first difference, the series become stationery thus I(1). By $Min^m\ t - stats$ of ZA, if the series attain stationarity upon first difference, then it is intuitively co-integrated. Consequently, we proceeded and tested the cointegration by Johansen and GH techniques as in Table 3 [65,96]. According to Table 3, where we reported t, $t{-}max^m$, ADF and z_t statistics evaluated on H_0 that ln Ff_t, ln Eu_t and ln GDP_t are not co-integrated displays statistical significance at 1% . For the L.H.S column, rejecting the statistics $r = 0$ at clearly indicates presence of at least one cointegration equation amongst the variables as $r = 1$ confirms the existence of 1 equation. On the Right hand side of Table 2, the respective statistics at intercept shift, regime, then intercept and slope shifts all confer to the presence of cointegration. Otherwise, the latter two break types confirm to a uniform date: 1987 when the sub-Saharan states shifted their economies unlike for the former. Automatically, 1987 herein commemorates to the period most of these states abandoned the highly input intensive and environmental degrading oriented (pre-industrial phase) to shifts in relatively lighter manufacturing and processing industries, information oriented and service industries. This saw the accidental alteration in the growth level of output, scale of environmental quality and changes in efficient energy use techniques. The changes downloaded up to the respective time series.

Table 4 accords the parameter estimated for both baseline VECM model (R.H.S column) and regime shift accounting equation in the L.H.S. All the $t - stats$ in the short run for both models are insignificant except for Δ ln Eu_t with $t - stats$ of -2.02 at 5 %. In the long-run and for the adjustment speed, all the $t - stats$ for the model with regime shift are significant together with their break dummies except for the baseline models. From the results, in account of the changes in the structure of the economies, the environmental Kuznets curve does not exist due to validity of a U shaped curve. Our findings are supported by the findings of Gill, AR, KK Viswanathan, and S Hassan who found that in Malaysia, the insignificant co-efficient on GDP^2 rejected the transition of Environmental Kuznet Curve for carbon emissions [102]. But our findings are not in support of the findings of Dong K, *et al.* who found EKC existence within the Asia-Pacific nations, but an existence of N-shaped EKC in India based on the findings of Murthy K and S Gambhir Similarly, a 1% increase in output growth (GDP) and Efficient energy use positively affect environmental pollution by 1.38 % and negatively affect by 0.42 % respectively [103,104]. The findings of Sharma SS are similar to ours when they investigated the factors of carbon emissions (CO_2) for a global panel of 69 nations applying a dynamic panel data model [105]. The results revealed that increase in GDP and energy consumption increase environmental pollution. Our results are also supported by the results of Sorge L and A Neumann that both GDP and energy consumption lead to carbon emissions [106].

These findings in addition to the dummies (shift in economies) of GDP, Efficient energy use and (Nonrenewable) fossil fuel consumption significantly increase, decrease and decrease environmental degradation by 1.85%, 0.79 and 1.73 % respectively as supported by the results of Atkinson SE, Panel, Bernard JT, *et al.* Furthermore, in the long-run, the systems of environmental pollution self-adjust to equilibrium at speed of 52.4% to maintain the optimum level of environmental quality which sustained economic development for case of sub-Saharan states.

Granger Causality Test

We used Granger causality test to explore whether one-time series is vital in forecasting another one-time series based. In table 5, the causality of GDP, GDP squared and efficient energy use are significant at 5% except for fossil fuel consumption. These results are in support with the studies of Begum RA, *et al.* On the other hand, Efficient energy use is the main determinant to environmental pollution, economic growth and (Nonrenewable) fossil fuel consumption as supported by Stambouli AB [109,110]. Based on table 5 efficient energy use being the main determinant of environmental pollution. There is a need for sub Saharan African nations to adopt renewable sources of energy such as solar energy and hydroelectricity. Comparing the two models used in Table 5, the regime model explains better the degradation of environment at 86.1% unlike 21.1% with the baseline model. The regime model predicts the well environmental situation than the baseline model because of likelihood value which is higher. From their Cusum plots both model estimated parameters are stable at 5 %. In other words Table 5, above, which presents the Granger causality test findings, clearly displays the existence of causal relationships between economic growth, Efficient energy use and fossil fuel consumption.

Conclusion

Africa's greenhouse gas increased 12 times since1950 with metric tons of 311,000,000 in 2008. According Statista 423.37 million Metric tons of carbon emissions from fossil fuel were emitted in 2010 in the region of Africa [111]. A lot of carbon emissions have been emitted in Africa for a long period of time. According Andres RJ, *et al.* they stated that carbon emissions from nonrenewable energy (liquid and solid) has increased in Africa for a long period of time [112]. They used statistical analysis to reveal that South Africa is the leading with 38% followed by a combination of countries like Morocco, Algeria, Nigeria, Libya and Egypt which are responsible for 46%. The remaining countries are responsible for 16% of the carbon emission in Africa.

This study seeks to investigate the casual effect of energy use, and GDP on (Nonrenewable) fossil fuel consumption in sub Saharan Africa and to investigate the solutions to the challenge of Greenhouse gases. Very limited number of literature have examined the causal effect of energy use, and GDP on (Nonrenewable) fossil fuel consumption in sub Saharan Africa. However, most studies apply estimations without applying structural break. Other studies have used structural breaks but devoted to the estimation of long run relationships without estimation short run relationships. Our study estimated short run relationships alongside long run relationships. This study is different from most studies because we have included structural breaks to test for cointegration in the variables. In addition, the study also executed the Cusum test and ran diagnostic investigations to contrast the performance of the two models in Table 4. Figure 1 and 2 bears the Cusum test [100]. We analyzed the factors that contribute to the degradation of the environment using three variables in the context of EKC and structural breaks. We utilized ln Ff_t, ln Eu_t and ln GDP_t as proxies to pollution, efficient energy use and economic output respectively using a quadratic format of EKC. We employed PP and Zivot-Andrews unit root test, baselines and the Gregory-Hansen co-integration, baseline and regime accounting VECM and finally granger causality econometric techniques. The causality revealed bi-directional between among all variables. The Zivot Andrews and Gregory H test all confirmed to the presence of structural breaks and cointegration respectively in addition to the traditional test. The VECM under regime break prescribed and predicted the environmental issues by providing better results as compared to the baseline VECM. VECM regime break, revealed ln Ff_t, ln Eu_t and ln GDP_t together with their time dummies significantly predicted the level of environmental degradation as aforementioned in Table 5. Later, the system returns back to equilibrium at a rate of 52.4 % to maintain optimum pollution for life sustenance.

Based on the findings of this study, the study recommends that sub-Saharan Africa should thus adopt environmental friendly sources of energy like solar, wind energy; carbon price carbon capturing, utilization, carbon plants and hydropower and invest massively in energy research centers, concentrate more on improving the level of economic growth so that more resources can be channeled to environmental rejuvenation. Sub Saharan Africa must not give up on her effort of employing more energy-saving technology by her economic activities, as well as implementing policies that stimulate energy efficiency in sub Saharan Africa, in her effort to mitigate environmental effluence concerns as the economy develops. Governments should also create awareness and about the danger of (Nonrenewable) fossil fuel consumption and the value of renewable energy to the environment. Cutting down of tree for fuel should be seriously discouraged and encourage more tree planting to manage carbon emissions. In most sub Saharan Africa, polythene bags are used to light charcoal stove which have caused a lot of hazardous diseases. Government should ban the use of polythene bags to preserve the environment and the health of their citizens.

The Limitations of the Study

Our empirical results and findings were based on a particular combination of variables for concluding the causal effect of energy use, and GDP on (Nonrenewable) fossil fuel consumption in sub Saharan Africa from 1971 to 2014. One of the limitation is that there are not many studies done with a combination of the same variables used in this study. Few researchers have combined efficient energy use and fossil fuel consumption. It was a huge challenge to get literature based on the combination of variables in this study.

Author Contributions

Max William Ssali and Duncan Omenda Hongo were responsible for the conceptualization of the original idea, data analysis and methodology. Consolata Wairimu Nderitu was responsible forwriting—original draft preparation, Maurice SimiyuNyaranga was responsible for data collection and Jianguo Du was responsible for supervision. In general, we worked together as a team.

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