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ELECTRICITY GENERATION, ROAD SECTOR ENERGY USE AND ENVIRONMENTAL POLLUTION IN TEN SELECTED AFRICAN COUNTRIES

Akomolafe, K J
Department of Economics, Afe Babalola University, Ado-Ekiti, Nigeria
akjohn2@yahoo.com

Ogunleye, E O
Department of Economics, Afe Babalola University, Ado-Ekiti, Nigeria
edladipur@yahoo.com

Abstract

This paper examines the impact of electricity generation, economic growth, and road sector energy use on environmental pollution in ten selected African countries. It employs micro panel data framework to allow for differences in the form of unobserved individual country effect. Various panel estimation techniques like Pool regression, fixed effect, and random effect methods were used, but Hausman test showed that fixed effect was the most appropriate. Variables used are GDP (constant 2000 US$), Co2 emission (kt), Electric production (kWh), and road sector energy consumption (kt of oil equivalent).The countries were chosen based on data availability. The result shows that there is positive relationship between environmental pollution and electricity generation, and between environmental pollution and road sector energy use in the selected countries. However, the result shows that there is no evidence to support the presence of EKC in the countries examined. The paper concludes that African countries should start accessing renewable energy sources that are environmental friendly as their sources of electricity generation.

Key words: EKC, Environmental Pollution, Electricity Generation, Economic Growth, GDP, C_{o2}, Hausman Test, Fixed Effect, Random Effect

INTRODUCTION

Climate change is widely recognized as the most important environmental risk facing the world today. Recent international agreements, such as the Kyoto agreement, and Copenhagen agreement have set strict targets for the reduction of greenhouse gases. This has lead to an increase in the campaign for more environmentally-friendly means of energy generation. One of these means of energy generation is electricity generation. The generation and distribution of electricity has environmental impacts and effects, depending on which energy source is used. Fossil fuels are non renewable energy sources and may not offer a long-term sustainable option for electricity generation, but contribute immensely to greenhouse gas emissions. Their effects range from climate change at the global scale to local concerns such as noise or visual intrusion.

The efficient use of energy resources and maximization of efficiencies at all stages of the generation, distribution and use cycle must be developed further thus providing the best option for the protection of the environment. America and Europe are the largest contributors to the Greenhouse gas emissions worldwide, with Africa contributing meagerly .Although at present, the contribution of African countries to global greenhouse gas emissions is infinitesimal, but its share will grow over time, as poverty is eradicated by social and economic development (Omojolaibi, 2009).

Following the global economic crisis that started in 2008, African economic growth has been on the increase. According to World Economic Situation and Prospects 2012 report by the United Nations, it decreased from 6.5% in 2007 to 5.5% in 2008, to 1.7 percent in 2009, but increased to 4.7% in 2010, and it is projected to increase to 5.8% in 2012.On individual country basis, Angola is projected to have 9% in 2012, Ethiopia (8.1%) and Ghana (7.4%), Niger (8.5%) with Nigeria expected to have 6.8% growth. Following this, energy issues have moved higher in the development agenda of policy-makers. This was mostly prompted by the recognition that without energy, most development objectives, including the Millennium Development Goals, cannot be met. The increased economic activity no doubt will bring with it increase in electricity demand which will translate to increase in electricity generation, road sector energy use etc.

On the other hand, the increased economic activity will ultimately promote inclement environment. The relationship between economic growth and environmental pollution has been widely researched in what is known as Environmental Kuznets Curve (EKC) .It says that there is an inverted-U-shaped relationship between economic activity and the environmental quality.

This is to say that at the first stage of economic growth, environmental degradation increases as income increases, but begins to decrease as income goes beyond a turning point. According to EKC hypothesis, economic growth will be the remedy to environmental problems in the future. However, empirical results have been ambiguous in their conclusions. On one hand, several empirical studies have confirmed the existence of an EKC for different measurements of environmental degradation, e.g. Panayotou (1993), Selden and Song (1994),and Giles and Mosk (2003). On the other hand, some authors affirm that there is no evidence supporting the EKC hypothesis e.g. Torras and Boyce (1998), Cole and Elliott (2003). The steps taken by Africa countries towards achieving the Kyoto protocol agreement seem somewhat tentative. Little African countries have taken steps towards modern renewable energy. There are still continuous efforts towards using fossil fuel in electricity generation. As this continues, the contribution of African countries to the greenhouse emission will ultimately increase. This paper examines the impact of electricity generation, road sector energy use and economic growth on environmental quality in some selected countries in Africa viz. *Cameroon, Congo Republic, Cote d'Ivoire, Egypt, Ghana, Morocco, Nigeria, Senegal, South Africa, and Togo*. To the best of our knowledge, this is the first attempt to examine the effect of the three exogenous variables on environmental pollution in Africa. The recognition of these impacts will help in formulation of improved energy efficiency policy which will be supported by a wide range of measures that reduce the use of non-renewable resources and produce less waste.

The rest of the paper is organized as follows: Section 2 presents a brief review of related literatures; Section 3 presents overview of electricity generation and road sector in the selected countries; In section 4, the data sources and methodology are discussed; In section 5, empirical analysis and interpretation of results are presented while section 6 presents the summary of the work, policy implications, and concludes with some recommendations.

REVIEW OF LITERATURE

Many of the empirical evidences in literature have focused on relationship between energy consumption and environmental pollution especially in the selected countries. However, there are few empirical evidences on electricity generation and environmental pollution. Wolde-Rufael,(2010) believe that coal consumption is the major source of global warming as power plants that burn coal are the major contributors to rising atmospheric concentration of greenhouse gas emissions. According to Krewitt and Nitsch, (2003); Roth and Ambs, (2004); Vrhovcak *et al*., (2005), environmental damage costs of electricity generation represent the uncompensated monetary values of environmental and health damages it causes. These costs, sometimes called external costs, are imposed on society and the environment, and are not accounted for by the producers or the consumers of electricity. Bickel and Friedrich (2005); Oak Ridge National Laboratory (1995); and Spath (1999), estimated the social and environmental external costs of a centralized power source using a life-cycle analysis approach.

They concluded that Public health impacts dominate the environmental costs, accounting for more than 70% of the estimated external costs for fossil fuel–based power generation. Ferguson (2000) examined the relationship between economic growth and electricity consumption. He found a correlation between electricity use and wealth creation in 100 developing countries and the correlation is stronger between electricity use and wealth than between total energy use and wealth.

On the relationship between economic growth and environmental pollution, empirical studies (e.g. Grossman and Krueger 1991, Selden and song 1994, Rothman 1998) supported an inverted U-shaped relationship between environmental degradation and economic growth. All of these studies supported the hypothesis that environmental degradation increases initially, reaches a maximum and after that declines as economy develops further. Stern (2004) also provided the empirical support to EKC with the evidence that initially environmental degradation is increased and then falls with an increase in per capita income. Perman and Stern (2003) tried to validate the environmental Kuznets curve by using panel data approach to cointegration and confirmed the long run equilibrium stable relation between sulfur emissions and economic growth but failed to support the existence of the EKC.

Similarly, Asici and Atil (2011) investigated causal relationship between economic growth and environmental degradation for the low, middle and high income countries. They applied fixed effect and fixed effect instrumental variables regression and concluded that positive effect of income on environment degradation is stronger in middle income countries as compared to low and high income economies. Moreover, in high income countries, the effect is not only negative but also statistically insignificant. Thus, the results do not provide support for EKC hypothesis.

Peter and Jeffrey (2003) argued that heavy dependence on foreign direct investment contributes to the growth of carbon dioxide emissions in less developed economies of the globe and that domestic investment has no significant effect on CO2 emissions. Mheni (2002) tested for the existence of the EKC in Tunisia from 1980 to 1997, using time series data for CO2 emissions, along with fertilizers concentration and the numbers of cars in traffic; he estimates only a quadratic equation for all the pollution indicators. The author concluded that there is no evidence to support the EKC for any of these pollutants.

OVERVIEW OF ELECTRICITY GENERATION IN THE SELECTED COUNTRIES

Table 1 below presents an overview of electricity generation in the selected countries.

Table 1: Electricity Generation In The Selected Countries

Sources % of total	Cameroon	Congo Republic	Cote d'Ivoire	Egypt	Ghana	Morocco	Nigeria	Senegal	South Africa	Togo
Hydro	75.4%	99.4%	0%	11.2%	74.4%	4.5%	27.1%	9.5%	0.5%	74%
Gas	8.9%	0.4%	0%	68.4	0%	13.8%	64.1%	1.8%	0%	0%
Oil Sources	15.5%	0.2%	0%	19.7	25.6%	24.2%	8.8%	85.8%	0%	24.4%
Coal	0%	0%	0%	0%	0%	56.2%	0%	0%	94.2%	0%
Nuclear	0%	0%	0%	0%	0%	0%	0%	0%	5.1%	0%

Source: 2009 World Bank Indicator

The table shows that fossil fuel is the major source of electricity generation in the countries. Gas, oil and coal represent the major sources of electricity generation in the countries. Egypt and Nigeria, for instance, use more of gas and oil. The on-going electricity reform in Nigeria is tailored towards fossil fuel sources. Also, about 94% of total electricity generated in South Africa comes from coal source. The same goes for Morocco with about 56% and 24.2% of their 85% of her total electricity generated coming from oil source. No doubt, these non-renewable energy sources contribute in no small amount to environmental pollution in the countries.

OVERVIEW OF ROAD SECTOR IN THE SELECTED COUNTRIES

Apart from South Africa, Egypt and a few African countries where there are few intra rail transportation, road transportation is the major form of transportation in Africa. For instance, Nigeria, the second largest economy and the largest in population in Africa, has a very limited intra rail transportation. The implication of this is excessive pressure on the road, and increase in road sector energy use. Also, Most of the vehicles used in these countries are not fuel efficient. This is because they are vehicles used and dumbed for years in Europe before they are imported into the countries. New cars are usually found with the rich who constitute a tiny percentage of the population.

METHODOLOGY

All the data used were collected from World Development Indicator and the time dimension span from 1991 to 2008.Electricity production (kWh) was used to proxy electricity generation, CO2 emissions (kt) was used to proxy environmental pollution, Real GDP was used to proxy Economic growth, Road sector energy consumption (kt of oil equivalent) was used to proxy road sector energy consumption. All the variables are in their log form. The model is presented in a simple modified version of the EKC model given in the literature below:

$\ln C = \beta_{1+} \beta_2 \ln E_{it} + \beta 3 \ln Y_{it+} \beta 4 \ln Y^2 it + 5 \ln R_{it} +$

Where

lnY = log of real gdp expressed in constant 2000 US$,

lnC =log of Co2 as proxy for environmental pollution

lnE = log of Electricity generation

lnR= log of road sector energy use

= is specific effect

= is the error term

i stands for the cross sectional units which in this cases are ten countries while ***t*** stands for the time dimension from 1991 to 2008. The linear and non-linear terms of GDP (Yit & $Y^2 it$) were included in the model to validate the existence of Environmental Kuznets curve (EKC). EKC implies that environmental degradation increases with economic growth and environmental quality starts to improve after certain level of income. The theoretical expectation is that the coefficients of these variables should be significantly positive and negative respectively i.e.
$dC_{it} / dYit > 0$ and $dCit / dY^2 it < 0$.

There are different approaches that can be used in this analysis. These include (i) pooled ordinary least square (POLS), (ii) one-way fixed effects (OEF). It should be noted that fixed effects approach is better in case of unobservable country-effects and unobservable time effects and (iii) one way random effects is also used (Baltagi 2001).However In this study, we used the three methods and then perform diagnostic test to select which is most appropriate. The diagnostic tests are:

1) Hausman test to ensure that the model is devoid of and correlated random cross sectional effects

2) Redundancy test to ensure that the effects of fixed parameters are not redundant using the Fixed Redundant F-statistic test

Pooled Regression

This method assumes that the heterogeneous characteristics across individual or grouped being analyzed average out and is thus not significant in the analysis. Should this assumption holds, the relationship can be estimated using the OLS estimation method, as long as the OLS assumptions equally hold. Therefore, the relationship expressed in equation (1) can be stated in the equation (2) below:

$y_{it} = \alpha+\beta x_{it}+ \varepsilon it$ …………………………………….. 2

y_{it} = the dependent variables (the phenomenon whose variation we want to explain, using other phenomena assumed exogenous) for individual or group i at time t. x_{it}= the explanatory variables (the exogenous phenomena whose variation is not explained in the model) for individual or group i at time t. Beta = the parameter capturing the degree of influence of explanatory variables on explained variable $\varepsilon_{i\,it}$ = the error term.

Fixed Effects Regression Approach

This method recognizes the existence of heterogeneous characteristics. However, the method assumes that the expectation/mean of these characteristics over time for an individual is observable; and can be separated from the actual

The Random Effect Method

This method assumes that the mean of heterogeneous characteristic across individuals/groups is observable and common for each individual/group. The unobserved component of the heterogeneous (i.e. its deviation from the mean) is also assumed not to be correlated with the other explanatory variables; and hence can be housed in the equation error term.

ESTIMATION AND INTERPRETATION OF THE PANEL MODELS

Given the data set, we estimated the three models,

(i) Pooled OLS model

(ii) Fixed effects model

(iii) Random Effects model

The summary of the regression results and the necessary diagnostic tests are as presented in the Table 2 below.

Table-2: Pooled OLS Result

VARIABLES	DEPENDENT VARIABLES =lnC02		
	Coefficient	t-statistics	*p*-value
LNELE	0.245538*	4.989194	0.0000
LNGDP	-2.830278*	-4.724072	0.0000
LNGDP^2	0.066753*	5.288675	0.0000
LRSEC	0.605562*	12.41046	0.0000
F-statistic	1304.462*		
R-squared	0.967550		
Adjusted R-squared	0.966808		

Note: * indicates significant at 1% level.

For the pooled regression, the estimated results reveal that linear and non-linear terms of GDP have negative and positive effect respectively on environmental pollution .This conflicts with the EKC, meaning that there is no existence of inverted U-shaped relationship between economic growth and environmental degradation in the countries examined. However, this result may be due to few data available.

However, there is a positive relationship between electricity generations and environmental pollution, and between road sector energy use and environmental pollution. Both road sector energy use and electricity generation contribute significantly to environmental pollution within the countries investigated. Going by the relative magnitudes of the coefficients of the variables, energy use contribute more. All the variables are statistically significant as indicated by their probability values. The F-test is also significant indicating the best fit of the estimated model.

We proceed to analyse the fixed effect and random effect regressions so as to determine the most suitable one. The results are shown in table 3 below

Table-3: Fixed and Random effect results

VARIABLES	**DEPENDENT VARIABLES = lnC02**					
	Fixed effect result			**Random effect**		
	Coefficient	t-statistics	*P*-value	Coefficient	t-statistics	*P*-value
LNELE	0.159839**	2.227889	0.0272	0.222822*	3.440018	0.0007
LNGDP	-1.276818	-0.900748	0.3690	-1.360747	-1.092142	0.2763
LNGDP^2	0.035570	1.189415	0.2360	0.038035	1.439625	0.1518
LRSEC	0.319181**	3.460946	0.0007	0.350891*	4.311451	0.0000
F-statistic	1333.898**			92.83236		
R-squared	0.990518			0.679680		
No of Cross units (Countries)	10					
Sample Period	1991-2008					
No of Observation	180					
Diagnostic Tests						
Redundant Fixed Effects Tests	F –Sta 44.677565* (9.1 d.f) P-value: 0.0000					
	Chi-square 221.455134* (9 d.f) P-value : 0.0000					
Hausman Test	Chi-square : 10.373970 (4 d.f) P-value : 0.0346					

Table 3......

Cross sectional Fixed effects		
Countries	CROSSID	Effect
Cameroon	1	-0.841349
Congo, Rep.	2	-0.652295
Cote d'Ivoire	3	-0.063642
Egypt, Arab Rep.	4	0.410014
Ghana	5	-0.246751
Morocco	6	0.216674
Nigeria	7	0.805216
Senegal	8	-0.138269
South Africa	9	1.019433
Togo	10	-0.509030

Note:* indicates significant at 1% level ** indicates significant at 5% level.

Diagnostic Test Analysis

Two diagnostic tests were conducted, namely; Hausman specification test for possible correlated random effect in the mode and the redundancy test on the fixed effects model. The starting point is the Hausman specification test. The null and alternative hypothesis are specified next:

H_0: $\text{var}(b) = \text{var}(\beta) \Rightarrow$ there is correlated random effect

H_1: $\text{var}(b) \neq \text{var}(\beta) \Rightarrow$ there is no correlated random effect

The Hausman diagnostic test (Chi-sq=10.373970 Prob=0.0346) shows that the null hypothesis is rejected at 5% significant level. Thus, there is no significant correlated random effect in the model. Hence we conclude that the fixed effect model significantly perform well than the random effect. To further confirm whether the Fixed effects model is actually the best model, we conducted redundancy test on the fixed effects model and the result as shown in table 3 above shows that the fixed effects are not redundant.

In summary, diagnostic tests show that there is no random effect and redundancy fixed effects; we thus adopt the results from the fixed effect model as basis to interpret the relationship between the dependent variable and independent variables in our model.

Interpretation of the Fixed Regression

In term of relative effects of the explanatory variable on the dependent variable, there is a positive relationship between electricity generation and environmental pollution in the countries investigated.. This is also significant as shown by the *p*-value. However, the estimated results reveal that the linear and non-linear terms of GDP have negative and positive effect respectively on environmental pollution .This also conflicts with the EKC meaning that there is no existence of inverted U-shaped relationship between economic growth and environmental degradation in the countries examined. However, the *p*-values also show that both linear and nonlinear forms of GDP are not statistically significant. As said earlier, this could also be a result of few data available for each country. There is also a positive relationship between road sector energy use and environmental pollution. The *p*-value also shows that road sector energy use is statistically significant in explaining variation in pollution the countries. The $R^2$is very high showing that about 99% variation in environmental pollution is explained by the explanatory variables. The overall level of significance also confirms this..

We also report the cross section fixed effects for each country used in the study. South Africa has the highest individual country effect than all others examined. This is no surprising as it is confirmed by the size of their economy. Nigeria and Cameroon also have high individual country effects.

CONCLUSION

The paper is a micro panel analysis of the relationship between electricity generations, economic growth, road sector energy use and environmental pollution in ten selected African countries. A fixed effect model was used as indicated by the diagnostic test. The result shows that there is no evidence of EKC in the countries selected .The result also shows that economic growth is not a significant determinant of environmental pollution in the countries. However, that there is a positive relationship between electricity generation and road sector energy use, between electricity generation and environmental pollution. The results were also significant.

The implication of the result is that the continuous use of fossil fuel as energy source in these countries will only add to environmental problem in the countries. It also shows that transportation system in the countries have not been environmental friendly.

With the continuous increase in economic activities, accompanied by increase in electricity demand and generation, time is not long when African contribution to the green gas emissions will increase.

To avoid this, African countries must move away from non-renewable energy sources and adopt renewable energy sources. Also, African countries must change from over-reliance on road transportation and adopt other modern means of transportation. Also, the demand for used cars that should be discouraged, and fuel-efficient cars brought to the countries.

This study is limited in the sense that the analysis is based on micro panel between the periods of 1991 and 2008. This is because of data availability. However, a macro panel analysis of a higher number of observations could yield a better result. This can be looked at in future research.

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