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# Environmental quality and economic growth in Nigeria: A fractional cointegration analysis

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## Abstract

The paper investigates the relationship between environmental quality and economic growth in Nigeria using a fractional cointegration analysis over the period 1970-2011. It seeks to examine the effect of growth on environmental performance by controlling for the role of institutional quality, trade openness and population density. The paper found that early stages of development in Nigeria accentuate the level of environmental degradation. It also finds that weak institutions and unrestricted trade openness increase the extent of environmental degradation due to environmental dumping. Finally, the paper shows that a larger population density enhances the promptness of environmental abatement measures and consciousness for cleaner environment. The study, however, failed to attain a reasonable turning point and hence a non-existence of EKC in Nigeria. The paper recommends the need to restrict the importation of emission intensive products, check the activities of multi-nationals which invest in producing high $CO_2$ emitting goods in LDCs and exports to home countries. Finally, there is need to strengthen institutional quality to ensure adoption of clean technologies as income rises.

***Keywords:*** Fractional cointegration, Institutional quality, Environmental degradation



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## 1. Introduction

Can economic growth be witnessed without deterioration in the quality of the environment? Does increase in income improves or worsens environmental performance? Would economic growth still remain attractive considering the unfavourable consequences on the environmental quality? These are basically issues encountered when observing the relations between economic growth and environmental quality. The observed and huge improvements in the living standard in the past decades have not come without a cost. Air pollution (smoke and noise), municipal waste problems, loss of forest areas, habitat destruction, threats to biodiversity, resource depletion, and the global green house problem are not unconnected with economic growth. As the process of growth continues, a critical collapse of the world economy due to environmental problems becomes evident. This constitutes a situation in which the success of growth leads to its own demise and generates adverse effects on an economy (Kemp-Bendict, 2003; Smulders, 2000); most especially in an economy with weak institutional quality. An instance is the case of Nigeria with the advent of crude oil. The witnessed exploitative oil induced growth has accentuated the level of environmental degradation most particularly in the oil producing areas. The Nigeria's scenario is largely due to weak institutions, as no feasible abatement measures have been implemented despite the increasing environmental degradation.

Conversely, increasing growth enhances the productivity of the economy and enables it access more advanced levels of technological knowledge. This raises productivity per unit of natural resource used thereby allowing larger volumes of production at lower rates of environmental degradation. Advancement in technological progress coupled with increasing economic growth would create the opportunities and resources to finance investments in new environmentally friendly technologies, to solve waste problems and reduce material and resource use. Despite the growth experienced from factor endowments in most developing Africa, poor quality institutions, weak rule of law, absence of accountability and high level of corruption have been responsible for the increasing level of environmental degradation (Simulders, 2000).

The EKC initially originated from the inverted U-shaped income distribution of Simon Kuznets, known as the Kuznets Curve. The Kuznets Curve hypothesis posits that at lower levels of per capita income, income distribution is skewed toward higher income levels implying that inequality is high but as income rises, skewness is reduced (Yandle et al., 2004). In 1991, Kuznets hypothesis took a new dimension. It became a tool for describing the income-pollution relationship. That is, how environmental quality (such as concentration of sulphur dioxide emissions) relates with per capita income. Kuznets suggests an evidence of similar inverted U-shaped relationship between level of environmental degradation for some pollutants and per capita income. Lakshmi and Sahn (2012, p. 2) says that "The EKC statistical relationship suggests that as development and industrialization progress, environmental damage increases due to greater use of natural resources, more emission of pollutants, the operation of less efficient and relatively dirty technologies, high priority to raise material output and less regard for environmental consequences of growth". As the rate of growth of an economy increases, life expectancy is enhanced; improved quality and cleaner habitat become more valuable. As an economy reaches the post industrial stage, cleaner technologies shift to information and service-based activities and willingness to enhance environmental quality improves the quality of environment- which is the realization of EKC (Lindmark, 2002).

Several similar studies discover the existence of a bell-shaped relation between the levels of environmental quality such as the concentration of sulphur dioxide emission, and per capita income (Azomahou and Van plus 2006; Stern, 2004; Kemande 2010; Yi et al. 2008). The examination of EKC relationship is essential for Nigeria as her major foreign earning economy activities is pollution-intensive. Statistics show that between 1973 and 2008, the share of crude oil and gas production in total GDP ranged between 21.1 percent and 37.5 percent; whereas, output from the service sector (with less pollutants) has been between 6.7 percent and 16.3 percent for the same period (CBN, 2009). Also, since 1961 Nigeria's ecological footprint balance sheet has consistently been on deficit, with marginal improvements in recent years. The balance for 2010 was 0.3 from a deficit of 1.92 in 1964. Further, there is the need to investigate the nature of the skewness of the Nigerian economy towards exploration and exportation of commodity goods (factor endowment with possibility of greater pollution), coupled with the prevalence of weak institutional quality and gross neglect of environmental abatement measures. It, therefore, becomes imperative to investigate the growth impact on environmental degradation and estimate the feasibility of EKC in the face of little or zero abatement (Ecological footprint Atlas, 2010).

Since the Kuznets original observation of the EKC, several studies have examined a vast variety of pollutants in estimating the EKC pattern depending on the nature of pollutants. Studies have shown that local externalities generating pollution tends to gradually vanish even at the low income levels, that is, pollution improves even at lower income. For some local externalities such as particles in water (Fecal Coliform) and indoor domestic pollution, pollution tends to decrease steadily with economic growth with no turning point. This does not contradict the EKC as pollution must have increased at some point in order to decline with increasing income. Some empirical investigations suggest that pollution involving very dispersed externalities tend to have their turning points at the highest incomes or no turning points at all, as pollution appears to increase steadily with income. An instance is carbon emission where an improved technology to abate such emission are capital intensive. This is not a sufficient condition for the rejection of the EKC because the turning points for such pollutants may come at levels of income per capita higher than in today's wealthiest economies (Arik, 2007).

Brock and Tylor (2005) view the EKC relationship from three different perspectives: scale, composition and technique. Growing the scale of all economic activities proportionally will likely increase pollution as the economy grows. If such growth is not proportional but is accompanied by a compositional change of goods produced, pollution may decline or increase with income. Similarly, when rich countries engage in production of less pollution-intensive goods, due to changing tastes or varying trade composition; the resulting effect will decline growth induced pollution. The increasing use of less pollution intensive production techniques will ultimately enhance growth and generates falling pollution level.

Beyond the several decomposition of EKC and assumptions under which the inverse U-shape pollution-income pattern of Kuznets is realizable, Stokey (1998) opines that many economies exhibit corner solution initially. This implies that residents of poor countries are willing to trade environmental quality for income at a faster rate than could be imagined using available technologies or resources (an instance is the case of local gold miners in Ghana). Levinson (1970, p. 2) opines that "as the economies become wealthier and their environment dirtier, the marginal utility of income falls and marginal disutility from pollution rises, to the point where people choose costly abatement mechanisms. After that point, the economies are at interior solutions where marginal abatement costs equal marginal rate of substitution between environmental quality and income, and pollution declines with income". The conclusions from the examination of the EKC coincide with the major findings from Grossman and Krueger (1995) that found no evidence that economic growth does unavoidable harm to the natural habitat.

The EKC hypothesis describes a long-term relationship between the level of pollution concentration - flow of emission and depletion of resources and economic growth. The study attempts to postulate whether there exist a U-shaped curve between emissions and economic development (Kemande, 2010). The EKC hypothesis postulates an inverted U-shaped hypothesis existing between income and environmental quality (see figure below). The table shows that with rising levels of income, pollution increases and the environment quality deteriorates; beyond some turning point (as abatement measures sets in) pollution declines and the environment quality improves with income (Yi et al., 2008; Yandle et al., 2002).

Similar trend is emphasised in the work of Chuku (2011). He stresses that EKC hypothesis postulates that economic development progresses from a relatively clean agrarian economy to a dirty industrial economy and finally returns to a clean environment with knowledge and services based economy.

Therefore, the paper seeks to examine the relationship between income and environmental quality in Nigeria covering the period 1990-2010 using a fractional cointegration approach. The remainder of the paper is as follows: the next section presents brief stylized facts on the income and Carbon emissions trend in Nigeria. The third section presents a brief literature review to identify previous findings on the thesis of the study. The fouth section presents an analytical framework and econometric analysis using the fractional integration and cointegration technique to examine the impact of $CO_2$ emissions on income, and the possibility of attaining an EKC. The fifth section concludes with policy recommendation.

## 2. Some stylized facts

According to the High Emission Scenario (HES), it is suggested that by 2025 Ghana, Nigeria and Sierra Leone will emit 4.4, 54 and 1.2 million tons of carbon respectively. This would amounts to seven, six and four folds increase over present emissions. However, emissions can be reduced by 36 percent, 25 percent and 13 percent respectively if adequate measures to conserve carbon are introduced as contained in the Low Emission Scenario (LES) (Omojolaibi, 2010).

Carbon emission tends to be falling at the higher level of income in the developed world while carbon emissions seem to be rising with income in the emerging economies of China, India, Brazil, Russia and Egypt (see Table 1). This indicates that the income level that would guarantee turning point in these economies is yet to be attained. However, South Africa reached a turning point at per capita income of US$3262.74 but the turning point failed to realize EKC as carbon emissions begins to dwindle at falling income. The experience in Nigeria appears to be inconsistent (see Figure 2) as $CO_2$ emissions has been falling with dwindling per capita income until 2005, when income begin to rise with fairly constant emissions.

Table 2 shows that carbon emitted in Nigeria per unit of transport energy used has been rising since 1980 due to the heavy dependence on petroleum based fuels while United States and China emits a relatively lower carbon; with the former having twice of Nigeria population and the latter having about 7 folds the size of Nigeria population. Likewise, $CO_2$ emissions from residential, commercial and public services in U.S.A continue to fall gradually since the 1990s but relatively on the increase in Nigeria until 2005. The evidences from our analysis is not unconnected with the intensive use of carbon concentrated fuels due to inefficient hydro generated power sources for manufacturing, residential and commercial uses.

## 3. Brief literature review

The environmental Kuznets Curve (EKC) hypothesis postulates that as income grows, pollution rises but subsequently decline if growth proceeds far enough. The reality of this statement represents a powerful and attractive policy message, suggesting that the pursuit of economic growth and cleaner environment can be attained simultaneously in the same time frame. That is, growth will eventually lead to greening over time after establishing a reasonable turning point- the income level beyond which growth causes pollution to decline (Deacon and Norman, 2004). Akbostanci et al. (2009, p. 6) describes "Environmental Kuznets Curve as an inverted U-shaped relationship between environmental degradation and income, is a hypothesized relationship between various indicators of environmental degradation and income per capita". The early stages of economic growth usually witness pollution increases but as income exceeds a certain threshold which varies for different indicators, the trend reverses; so that at high income levels, economic growth leads to environmental improvement (Stern, 2004; Azomahou and Van Phu, 2006; Yi et al., 2008; Panayotou, 2000).

The empirical work of Schmalensee et al. (1998) employs a spline function. The spline model is preferred to the polynomial specification due to its minimum approximation error. The study supported the evidence of EKC for $CO_2$ emissions with a reasonable using dataset from 141 countries for the period of 1950-1990. Galeoti et al. (2006) estimated the existence of EKC using a weibull functional form, the model was considered appropriate due to the simplicity in the interpretation of its parameters. The model was estimated by Maximum Likelihood (ML) on carbon emission for 125 countries. The findings appears mixed; with evidence of an EKC with reasonable turning point for the period 1960-1967 for OECD countries, while a concave pattern with no reasonable turning point is obtained for non-OECD countries during 1971-1997.

Aslanidis and Xepapadeas (2006) propose a 2-regime smooth transition regression (STR) model which is a more flexible parametric specification. The estimation of the model was carried out using non-linear least square (NLS). Aslanidis and Iranzo (2009) applied this methodology for 77 non-OECD countries over the period 1971-1997. Though the evidence of EKC could not be justified but the results reveal two regimes. First, a low income region where $CO_2$ emissions accelerate with growth; and second, a middle-to-high-income region associated with a deceleration in environmental degradation.

Studies adopting semi and non-parametric models specification for $CO_2$ emission obtain mixed results. Taskin and Zaim (2000) show an evidence of EKC for a panel of 52 countries over the period 1975-1990. Conversely, Bertinelli and Strobl (2005) and Azomahou et al. (2006) could not reject a linear (positive) relationship between per capita income and $CO_2$ emission; with the former using a panel of 122 countries between the period 1950-1990 and the latter adopted an extensive analysis on a panel of 100 countries for the period 1960-1996. Millimet et al. (2003) adopted a semi-parametric partial linear model for United States for the period 1929-1994 and obtained an evidence of EKC for Sulphur dioxides ($SO_2$) and Nitrogen Oxides ($NO_x$), and rejected the null hypothesis of a parametric model (a cubic or a piecewise linear line specification) in favour of a more flexible semi-parametric model.

Bertinelli and Strobl (2005) attempts examining the existence of an EKC in a cross country study using a semi-parametric regression estimator for 122 countries for the period of 1950-1990 and the result was unable to reject the linearity of the relationship between income and pollution. In another Similar studies, Bertinelli and Strobl (2004) and Nguyen-Van (2009) found evidences in support of EKC for $SO_2$ and $CO_2$.

Omisakin (2009) investigated the relationship between economic growth and environmental quality in Nigeria using Johansen cointegration analysis for the period 1970-2005 with no evidence to support EKC. Bello and Abimbola (2010) adopted an ordinary least square regression to investigate whether an EKC path exist for Nigeria as income grows for the period of 1980-2008. The study found a U-shaped relation between $CO_2$ emissions and GDP growth rate in Nigeria, and concludes that carbon emissions in Nigeria is not driven by economic growth.

Recently, methodological issues are centred on the possibility of obtaining spurious results in EKC investigations. Earlier studies neglect the fact that EKC regressions involve basically non-stationary variables- emissions and GDP. It is therefore worrisome to rely on such results if they exhibit a co-integrating property. More recent empirical investigations have drawn attention to the stationarity properties of the variables in the model (GDP per capita and per capita emission) and likewise on the co-integration property that must be present to achieve EKC, if unit root exists (Breitung and Pasaran, 2008; Pedroni, 2004; Galeotti et al., 2006; Maddala and Wu, 1999; Stern et al., 1996; Stern, 1998, 2004).

This paper builds on this method and departs from those used in earlier studies that assume the order of integration of a stochastic process can take on only integer values. This significant distinction makes the traditional unit root testing, say, a stationary I(0) (integrated of order 0) and a non-stationary I(1) (integrated of order 1) process too restrictive. Fractionally differenced processes are flexible as the order of integration does not need to be an integer but can take any value between zero and one. This process provides a more flexible framework for EKC model; as it allows for more possibilities for emissions and income to be integrated if they are non-stationary. Nektarios (2009) adopted the fractional integration approach and found an evidence of non-stationarity for carbon emissions and GDP per capita at the traditional I(0) and I(1) processes. Using a value of the (estimated) integration parameter of 0.5 as a threshold for fractional co-integration, the Kuznets pollution-income hypothesis was realized for only 5 out of 24 countries.

## 4. Analytical framework and methodology

### 4.1. Background

The study follows the empirical framework proposed by Fang, Miller and Teh (2012, p. 8) where the Environmental Kuznets Curve (EKC) based on an identity equating the environmental impact (I) to the product of population (P), affluence (A) proxied by GDP per capita and technology (T) or IPAT. The IPAT framework was formulated in a seminal paper by Ehrlich and Holdren (1971). According to Chertow (2001), IPAT is such that it can be written as:

$$I = P * A * T$$

As Kemp Benedict (2003, p.2) described; "...in this equation, because $P$ multiplied by $A$ is just GDP, the technology factor $T$ must be the ratio of the environmental impact to GDP. The Environmental Kuznets Curve hypothesis is a statement about $T$. It says that $T$ is a function of $A$ that increases at small values of $A$ and declines at high values of $A$". The functional form capturing any environmental Kuznets curve must reflect this relationship.

Commoner (1972) expresses the IPAT equation mathematically in a manner as such:

$$I = population * \frac{Economic\ good}{Population} * \frac{Pollutant}{Economic\ good}$$

The population captures the size of the country in a given year or a change in size over a given period. Economic good expresses the amount of a particular good produced or consumed in a given year and referred to as 'affluence'. Pollutants refer to the amount of a specific pollutant released. This measures the environmental impact resulting from a unit of production (or consumption) which reflects the nature of the productive technology. When simplified, the equation takes on the nature of a mathematical identity in the IPAT equation.

Grossman and Krueger (1995) specified the non-linear relationship between the indicators of the environmental pollution and per capita income in a reduced form equation. The model relates the level of pollution to the level of income per capita and which can be written in its linear explicit specification as follows:

$$COE_t = \alpha_0 + \alpha_1 Y_t + \alpha_2 Y_t^2 + X_t + \varepsilon_t$$

where t=1,...,T refers to time, $COE_t$ is a measure of pollution level ($CO_2$ emission), $Y_t$ is per capita GDP, $Y_t^2$ represents its geometric transformation and $X_t$ is a vector of other covariates while $\varepsilon_t$ is the normally distributed stochastic term.

Several studies have been criticized based on the omission of relevant explanatory variables, besides the usual income variables. There is the need to include an indicator of trade openness because of the so-called "pollution haven" or environmental dumping hypothesis (Galeotti et al., 2006; Hettige et al., 1992; Kaufmann et al., 1998; Suri and Chapman, 1998). In addition, allowance should be made for the inclusion of the role of institutions. Institutional quality has been noted to play an important role in managing the economy following the seminal work of North (1991). Sound institutional quality has been adjudged as imperative for factor driven economy (Global Competitiveness Report, 2012) as inappropriate institutional arrangements and policies in an economy can lead to sub-optimal economic performance (Temple, 1993).

## 4.2. Model specification

The empirical framework of this paper draws from the Grossman and Krueger (1995) reduced form equation used to investigate the relationship between economic growth and $CO_2$ emissions. Considering the gaps in the literature, this paper attempts to build an augmented pollution-income model which can be specified as follows:

$$COE_t = \alpha_0 + \alpha_1 Y_t + \alpha_2 Y_t^2 + \alpha_3 Y_t^3 + X_t + \varepsilon_t$$

where $X_t = \begin{pmatrix} FDI_t \\ TON_t \\ CC_t \\ PD_t \end{pmatrix}$, $\varepsilon_t$ is the error term. $TON_t$ stands for trade openness, $CC_t$ is the control of corruption and $PD_t$ is the population density.

The dependent variables $COE_t$ is the $CO_2$ emissions (in metric tons), the choice of the carbon dioxide as a measure of pollution hinged on the fact that $CO_2$ emission is the main component of the greenhouse gas (Carvalho and Eduardo, 2008); Galeotti et al. (2006). The variable $Y_t$ and its quadratic and cubic transformation capture the shape of the EKC function. $Y_t$ shows that early stages of development accelerate the environmental degradation. In this respect, Stern (2004) found an increase in pollution indicators at early developmental stages. The $Y_t^2$ and $Y_t^3$ corroborate to indicate if there is an inverted U-shaped, implying the realization of the EKC. $FDI_t$ , $TON_t$ , $CC_t$ , and $PD_t$ are indicators of foreign direct investment, trade openness, institutional quality and population density respectively. The indicator of foreign direct investment and trade openness is required to control for the level of environmental dumping by multi-nationals while control of corruption measures government efficiency in adopting cleaner technologies and relevant abatement measures with rising income. The population density variable is needed in the model as a country with high population density attracts a greater social conscience about environmental problems than a sparsely populated country (Selden and Song, 1994).

## 4.3. Techniques of estimation

### *4.3.1. Fractional integration and co-integration*

The traditional unit root test employed in empirical studies where the order of integration of a time series is allowed to take only integers values could have resulted in an unrealistic realization of EKC. In this investigation of EKC in Nigeria, it is imperative to allow for fractional degree of integration in explaining the stochastic trend in the series involved (Nelson and Plosser, 1982; Box and Jenkins, 1970). In particular, a linear combination between pollutant and income may results to a valid EKC, assuming the series are integrated of order one and EKC may not arise, if integrated of order zero. The implication of fractional differencing is that there is a continuum of possibilities for time series to cointegrate bringing about the realization of EKC. Therefore, in overcoming the zero-one divide (Galeotti et al., 2006), the study used fractional co-integration method which is the generalized version of co-integration to examine long-run equilibrium relationship on a fractional domain. At difference $d$ times, makes the times series $z_t$ integrated of order I($d$) stationary, that is, $\Delta^d z_t = (1-L)^d z_t$ is I(0), where $L$ is the lag operator where $Lx_1 = x_{t-1}$. If the parameter $d$ is assumed to take any real value; the fractional differencing operator is defined as follows according to Lee et al. (2010):

$$(1-L)^d = \sum_{k=0}^{\infty} \frac{\Gamma(k-d)L^k}{\Gamma(-d)\Gamma(k+1)}$$

The $\Gamma(.)$ represents the gamma function, the arbitrary restriction of $d$ to integer values results to the standard autoregressive integrated moving average (ARIMA) model (Lee S, Jiang I and Liu Y, 2010). The [0-1] interval is subdivided into regions with specific interpretations for different values of $d$. If $d$=0, the process $z_t$ is stationary and possesses short memory since its autocorrelations die away very rapidly, i.e. invertible ARMA modelling. The process is still stationary but its autocorrelation takes longer time to vanish for 0<$d$<0.5. At 0.5≤$d$<1, the process is no longer stationary but it is mean reverting (shocks to the series tend to disappear in the long-run) no long-run impact of an innovation on the future values of the process. If $d$≥1, the process is non-stationary and non-mean reverting. Finally, if -0.5<$d$<0, the process exhibits intermediate memory or long-range negative dependence (Granger, 1980; Hosking, 1981; Gil-Alana, 2006).

According to Galeotti et al. (2009, p. 11) a vector of variables $z_t$ components are fractionally cointegrated of order ($d,b$) when the following conditions are satisfied:

> "First, all components of $Z_t$ are I($d$). Second, there exists a cointegrating vector $\beta$ such that $\beta' Z_t$ is I($d$-$b$) with $b$>0. In testing for fractional cointegration, a two-step procedure can be used. First, the order of integration for each component of $Z_t$ has to be estimated and its statistical significance tested. Secondly, if all components of $Z_t$ have the same order of integration, say $d$, the residuals from the cointegrating regression can be estimated and their order of integration tested. If the null hypothesis that the order of integration of the residuals is equal to $d$ cannot be rejected, then the series are not fractionally cointegrated. Conversely, if the null hypothesis is rejected in favour of a degree of integration which is less than $d$, then the series are fractionally cointegrated. The process can be completed by applying the same statistics for fractional integration to estimating the cointegrating residuals".

## 4.4. Data sources and measurements

The sources and measurements of the data employed in the study are presented in Table 3. The data are sourced from the World Development Indicators (2012) of the World Bank, except the indicator of institutional quality – control of corruption which is obtained from World Governance Indicators, 2012 of the World Bank. The study carried out a fractional cointegration analysis in investigating the relationship between environmental quality and pollution in Nigeria covering the period 1970-2011.

### 4.5. Descriptive analysis

Table 4 presents the summary statistics of the dependent and explanatory variables considered in the study. It shows the mean values for individual series as well as the standard deviation, minimum and maximum values for all the variables in the model. The mean value for $CO_2$ is calculated at 62008.03 kilo tons (kt) and per capita income stood at US$390.48. In the same manner, the mean of control of corruption is negative at -1.112. The negative value is not unconnected with the prevalence of corrupt practises in Nigeria.

The study also conducted the pair-wise correlation matrix as contained in Table 5, in order to examine the possibility of the presence of strong correlation among the explanatory variables. The results obtained indicate no serious problem of multi-collinearity since there is no incidence of perfect correlation among the explanatory variables.

## 5. Results and discussion

### 5.1. Fractional integration

In economic principle, the *d* parameter is used to determine the extent or degree of persistence in the series. Table 6 below shows the interpretations for the values of *d* and the parameter value for fractional integration. In estimating the fractional order of integration of the series involved, two semi parametric methods are employed. The spectral regression or the GPH (Gweke and Porter-Hudak, 1983) estimation and the Guassian semi-parametric approach (Robinson, 1995) estimation. Both techniques are used to determine the value of the differencing parameter *d* for the series involved.

Since the differencing parameter *d* for $lco_2$ is 0.04344, the log of $CO_2$ emissions appears to be stationary, mean-reverting and possesses a finite variance- effect of shocks in the system die away very rapidly. Therefore, we failed to reject the null hypothesis that $d$=0. The *d* values for lrypc and lrypc3 indicate that the log of GDP per capita and its cubic transformation are non-stationary, non-mean reverting and possesses an infinite variance, i.e. its autocorrelation failed to vanish with time; while the log of the quadratic transformation of GDP per capita though mean-reverting but non-stationary, as shocks to the series tends to disappear only in a very long-run. The values of the differencing parameters for lton, lpd and cc which are 0.743, 0.998 and 0.933 respectively indicate that the log of trade openness, population distribution and control of corruption exhibits a long-lived shock duration (i.e. it takes a long time for their means to revert) and non-stationary, while the log of foreign direct investment appears to be stationary and mean-reverting. All the variables appear to be significant at 10 percent significance level except for $lco_2$, lfdi, and cc.

### 5.2. Fractional cointegration

Cointegration attempts to ascertain the possibility of obtaining a long-run equilibrium relationship among the fractionally integrated series. Since the differencing parameter of residual from the regression of the integrated series appears not to be less than *d*, we therefore accept the null hypothesis that the series are not fractionally cointegrated. Since the realization of EKC requires a long-run relationship between GDP per capita and $CO_2$ emissions, we can rightly conclude that there exists no evidence of EKC in Nigeria. The study found a positive linear relationship between income and indicators of $CO_2$ emissions, i.e. if per capita GDP is raised by one percent, $CO_2$ will increase by twenty per cent. The negative magnitude of the quadratic transformation of GDP per capita, though, shows a possibility of EKC but was not found to be statistically significant in the realization of EKC in Nigeria. The results from our estimation show a positive relationship between foreign direct investment, trade openness and $CO_2$ emissions. It indicates that a one percent increase in fdi and ton results in 0.55 per cent and 0.002 per cent respectively in carbon emissions. The control of corruption and population density indicators collectively exerts an inelastic impact on $CO_2$ emissions, i.e. improvements in institutional quality, particularly control of corruption will reduce the level of carbon emissions. Similarly, as population density intensifies, there are more consciousnesses as well as pressure for cleaner environments.

The study found that the early stages of development accelerates the rate of environmental degradation, as indicated by the coefficient of GDP per capita which is consistent with Stern (2004). Also, the indicator of GDP per capita was found not to be stationary as against the work of Bello and Abimbola (2010) who use the traditional integration technique. Finally, the study found no significant evidence to support the existence of Environmental Kuznets Curve in Nigeria, as the sign of the quadratic transformation of the GDP per capita, though negative, is not significant.

## 6. Summary and conclusion

The study attempts an investigation of the relationship between environmental quality-carbon emissions and economic growth in Nigeria using a fractional cointegration analysis over the period of 1970-2011. The model used in the study recognises the role of institutional quality, trade openness and population density which makes the study unique from previous attempts. These added indicators appear to play a significant role in the dynamics of Carbon emissions in Nigeria; institutional quality, particularly control of corruption has been adjudged as imperative for factor driven economies. The level of trade openness helps to curtail the environmental dumping or pollution haven from globalization and a large population density helps increase consciousness for cleaner environmental and prompt abatement measures. The introduction of fractional cointegration in examining the pollution-income relationship and the inclusion of institutional indicator represents the major contributions of this work. Following the backdrops from the findings above, the policy drivers are advised to embark on policies that restrict importation of carbon intensive products and check the activities of multi-national companies producing carbon intensive goods in poor country for use in the home countries. Similarly, institutions needs to be strengthened to ensure appropriate abatement measures and adoption of cleaner technologies in order to mitigate the rising emissions associated with early development stages.

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## Appendix

**Table 1.** Per Capita $CO_2$ emission and Per Capita GDP

| | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2008 |
|---|---|---|---|---|---|---|---|
| U.S.A- $CO_2$ | 20.78 | 18.86 | 19.55 | 19.67 | 19.54 | 18.93 | - |
| YPC | 1328.99 | 1396.56 | 1491.21 | 1653.84 | 1943.3 | 2433.76 | 3235.36 |
| Japan- $CO_2$ | 8.57 | 8.02 | 8.86 | 9.44 | 9.61 | 9.69 | - |
| YPC | 23021.73 | 27449.52 | 34236.71 | 36177.03 | 37291.71 | 39295.31 | 39971.62 |
| China- $CO_2$ | 1.5 | 1.87 | 2.17 | 2.76 | 2.7 | 4.44 | 5.31 |
| YPC | 186.44 | 289.68 | 391.65 | 657.99 | 949.18 | 1464.11 | 2425.47 |
| India- $CO_2$ | 0.5 | 0.63 | 0.79 | 0.95 | 1.13 | 1.24 | 1.46 |
| YPC | 230.01 | 263.96 | 316.43 | 367.28 | 450.42 | 577.66 | 794.81 |
| Brazil- $CO_2$ | 1.54 | 1.33 | 1.4 | 1.7 | 1.89 | 1.88 | 2.05 |
| YPC | 3536.05 | 3334 | 3352.97 | 3606.01 | 3696.15 | 3976.7 | 4716.6 |
| Russia- $CO_2$ | - | - | | 11.4 | 10.62 | 11.29 | 12.04 |
| YPC | - | - | 2602.25 | 1618.12 | 1775.14 | 2442.96 | 2930.04 |
| South Africa-$CO_2$ | 8.28 | 10.36 | 9.47 | 9.04 | 8.38 | 8.65 | |
| YPC | 3463.25 | 3262.74 | 3151.84 | 2960.42 | 3019.95 | 3397.72 | 3753.47 |
| Egypt-$CO_2$ | 1.01 | 1.26 | 1.34 | 1.54 | 2.09 | 2.35 | 2.69 |
| YPC | 856.6 | 1052.85 | 1153.68 | 1248.73 | 1475.84 | 1600.32 | 1975.55 |
| Nigeria- $CO_2$ | 0.9 | 0.81 | 0.47 | 0.32 | 0.64 | 0.74 | 0.64 |
| YPC | 416.34 | 314.07 | 358.55 | 359.43 | 371.77 | 442.72 | 540.21 |

*Source: Computed from World Development Indicators, 2012*

**Table 2.** $CO_2$ Emissions as percentage of total fuel combustion

| | | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2008 |
|---|---|---|---|---|---|---|---|---|
| Manufacturing, Industries and construction | U.S.A | 20.4 | 16.8 | 14.4 | 11.5 | 11.7 | 10.9 | 11.3 |
| | China | 46.5 | 43.9 | 40.9 | 39.9 | 31.8 | 31.5 | 33.3 |
| | Nigeria | 17.6 | 15.7 | 17.3 | 14.4 | 10.1 | 8.8 | 10.1 |
| Residential, Commercial & public services | U.S.A | 13.7 | 12.5 | 11.1 | 11.2 | 10.4 | 9.8 | 9.9 |
| | China | 17.3 | 18.7 | 16.5 | 11.7 | 9 | 6.7 | 6.2 |
| | Nigeria | 9.6 | 12.9 | 14.3 | 12.4 | 9.9 | 6.9 | 4.8 |
| Transport | U.S.A | 26.5 | 28.3 | 29.2 | 29.8 | 30 | 31 | 30.2 |
| | China | 5.7 | 5.8 | 5.3 | 5.1 | 7.2 | 6.6 | 7 |
| | Nigeria | 49.9 | 41.7 | 40 | 39.6 | 51.3 | 50.1 | 48.6 |

*Source: Computed from World Development Indicators, 2012*

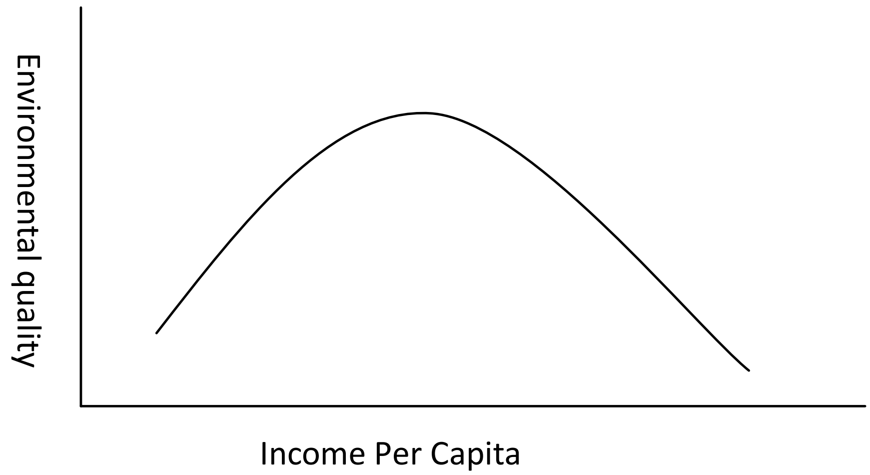


**Figure 1.** Kuznets Pollution-Income relationship

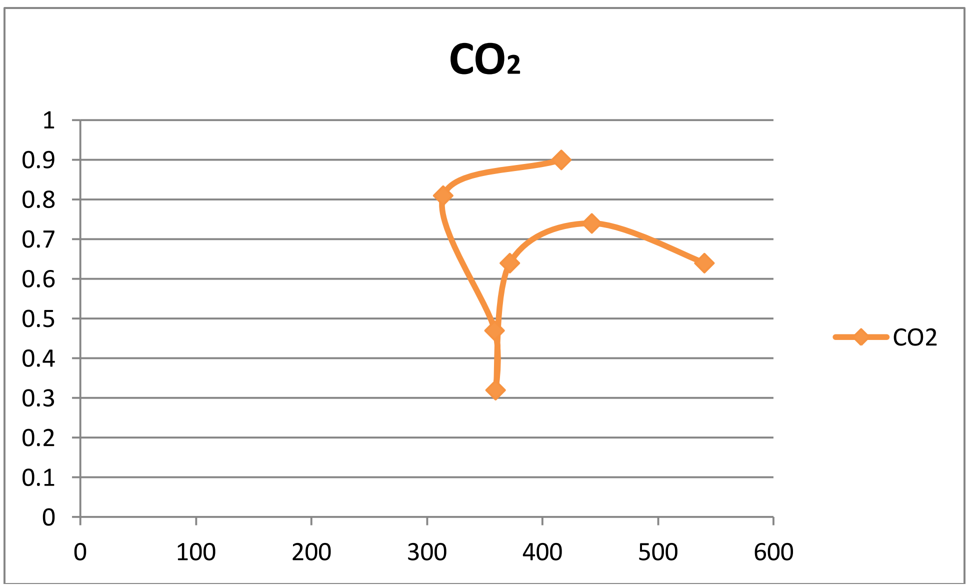


**Figure 2.** Pollution-income relationship in Nigeria (Source: Computed from World Development Indicators 2012 Statistics)

**Table 3.** Data sources and measurements

| Variable | Description | Source | Measurement |
|---|---|---|---|
| RYPC | GDP Per Capita Income | World Development Indicators (WDI) of World Bank | Constant US$ 2000 |
| FDI | Foreign Direct Investment | World Development Indicators (WDI) of World Bank | Constant US$ 2000 |
| TOPN | Trade Openness | World Development Indicators (WDI) of World Bank | (Import + Export)/GDP |
| CC | Control of Corruption | World Governance Indicators (WGI) of World Bank | Ratio |
| PD | Population Density | World Development Indicators (WDI) of World Bank | Number |

*Source: Computed by authors*



**Table 4.** Summary of Statistics

| variables | obs | Mean | Std.dev | min | Max |
|---|---|---|---|---|---|
| $co_2$ | 39 | 62008.03 | 20880.49 | 21539.96 | 104043.8 |
| rypc | 42 | 390.4847 | 61.42995 | 293.5969 | 561.9044 |
| fdi | 41 | 1.61E+09 | 2.19E+09 | -7.39E+08 | 8.55E+09 |
| topn | 42 | 0.582147 | 0.210265 | 0.196206 | 0.973212 |
| cc | 16 | -1.11154 | 0.150601 | -1.33 | -0.81 |
| pd | 41 | 110.6017 | 32.8688 | 62.97668 | 173.9442 |

*Source: Computed by authors*

**Table 5.** Correlation Matrix

| Variable | lrypc | Lfdi | ltopn | cc | Lpd |
|---|---|---|---|---|---|
| lrypc | 1 | | | | |
| lfdi | 6160 | 1 | | | |
| ltopn | 0.3038 | 0.7186 | 1 | | |
| cc | 0.5195 | 0.6524 | -0.315 | 1 | |
| lpd | 0.3634 | 0.8885 | 0.8038 | 0.4909 | 1 |

*Source: Computed by authors*

**Table 6.** Parameter Value for Fractional Integration

| *d* value | Interpretation | variance | Shock duration | stationarity |
|---|---|---|---|---|
| *d* = 0 | Deviations follow a stationary and possesses short memory since its autocorrelation die away very rapidly, i.e. mean-reverting process | Finite | Short-lived | Stationary |
| 0<*d*<0.5 | Deviation follows a stationary and mean-reverting process; however its autocorrelations take more time to vanish | Finite | Long-lived | Stationary |
| 0.5 ≤ d<1 | Non-stationary but still mean reverting. shocks to the series tend to disappear in the long-run | Infinite | Long-lived | Non stationary |
| *d* ≥ *1* | Non-stationary and non mean reverting | Infinite | Infinite | Non stationary |

*Source: Tkacz, 2001; Galeotti M et al 2006; Lee S et al 2010*

**Table 7.** GPH Estimates for *d*- differencing parameter

| variable | power | ords | Est *d* | t(H0: *d* =0) | Prob |
|---|---|---|---|---|---|
| lco2 | 0.5 | 7 | 0.4344 | 0.0804 | 0.94 |
| lrypc | 0.5 | 7 | 1.00706 | 2.2591 | 0.087 |
| lrypc2 | 0.5 | 7 | 0.711646 | 2.8539 | 0.046 |
| lrypc3 | 0.5 | 7 | 1.00706 | 2.2591 | 0.087 |
| lfdi | 0.5 | 7 | 0.396075 | 1.0771 | 0.342 |
| ltopn | 0.5 | 7 | 0.742648 | 1.4669 | 0.216 |
| Cc | 0.5 | 7 | 0.93293 | 0.6912 | 0.615 |
| lpd | 0.5 | 7 | 0.998524 | 99.5925 | 0 |

*Source: Computed by authors*

**Table 8.** Robinson Estimate for *d*-differencing parameter

| variable | power | ords | Est *d* | t(H0: *d* =0) | Prob |
|---|---|---|---|---|---|
| lco2 | 0.5 | 6 | -0.281985 | -0.695 | 0.507 |
| lrypc | 0.5 | 7 | 0.824723 | 2.2104 | 0.058 |
| lrypc2 | 0.5 | 7 | 0.824722 | 2.2104 | 0.058 |
| lrypc3 | 0.5 | 7 | 0.824722 | 2.2104 | 0.058 |
| lfdi | 0.5 | 7 | 0.33905 | 1.1741 | 0.274 |
| ltopn | 0.5 | 7 | 0.603665 | 1.4815 | 0.177 |
| Cc | - | - | - | - | - |
| lpd | 0.5 | 7 | 0.977052 | 145.3397 | 0 |

*Source: Computed by authors*