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Abstract

This study utilizes standard- and nested-EKC models to investigate the income-environment relation for Nigeria, between 1960 and 2008. The results from the standard-EKC model provides weak evidence of an inverted-U shaped relationship with turning point (T.P) around $280.84, while the nested model presents strong evidence of an N-shaped relationship between income and emissions in Nigeria, with a T.P around $237.23. Tests for structural breaks caused by the 1973 oil price shocks and 1986 Structural Adjustment are not rejected, implying that these factors have not significantly affected the income-environment relationship in Nigeria. Further, results from the rolling interdecadal analysis shows that the observed relationship is stable and insensitive to the sample interval chosen. Overall, our findings imply that economic development is compatible with environmental improvements in Nigeria. However, tighter and concentrated environmental policy regimes will be required to ensure that the relationship is maintained around the first two-strands of the N-shape

Keywords: *Environmental Kuznets curve, development,* CO_2 *emissions, nested-EKC model, Nigeria*

JEL Classification*: Q20, O10, Q25*

1. Introduction

The relationship between economic development and environmental quality is one of the most topical issues that have exercised the minds of contemporary development and environmental policy makers. This has particularly been so since the beginning of the 1990's when concerns regarding global warming, climate change and environmental degradation took centre stage after the publication of the 1992 World Development Report (World Bank, 1992). The common thinking is that there is an inverted-U shaped relationship between economic activity - usually measured in terms of per capita income - and environmental quality, usually measured in terms of air quality. That is, at the initial stages of economic development, environmental degradation increases as income increases. However, after a certain level of income (turning point), environmental degradation begins to decrease as development progresses. This hypothesized relationship between economic development and environmental quality is what has been dubbed as the Environmental Kuznets Curve (henceforth, EKC), apparently because it mirrors the relationship between economic development and income inequality first observed by Kuznets (1955).

The significance of the relationship between economic development and environmental quality is that it allows the policy-maker to ascertain the response of the environment to economic activities, thereby, forming the basis for sustainability planning. Studies on the EKC hypotheses have returned mixed results. Several studies have confirmed the existence of an EKC for different measurements of environmental degradation e.g. Panayotou (1993), Selden and Song (1994), Brajer et al. (2007), and Fodha and Zaghdoud (2010). On the other hand, some other studies report a monotonically increasing or decreasing relationship between pollution and per capita income e.g. Akbostanci et al. (2009), Holtz-Eakin and Selden (1995), De Bruyn et al. (1998) and Cole and Elliott (2003), and yet, another group of studies report an *N*-shaped relationship e.g. Friedl and Getzner (2003), Akbostanci et al. (2009) Martinez-Zarzoso and Bengochea-Marancho (2004).

The common denominator of most of these empirical studies is the use of cross-country panel data to investigate the EKC hypothesis. This trend has been criticized in the contemporary literature, particularly because of the observed heterogeneity among countries (see for e.g. He and Richard, 2010; Dijkgraaf and Vollebergh, 2005; Fodha and Zghdoud, 2010; Koop and Tole, 1999; and Stern, 2009). Hence, any potential inference drawn from these cross-country studies provides only a general understanding of how the variables are broadly related, and thus offers little guidance for policy formulation (Fodha and Zaghdoud, 2010). Therefore, it is more advantageous to conduct historical studies of individual countries, since this approach allows one to take into account, country-specific historical experiences, such as structural change, environmental polices, trade patterns and exogenous shocks that are peculiar to that country (Lindmark, 2002; Stern et al. 1996).

Further, most empirical works on the EKC hypothesis (apart from a few exceptions) have been based on heuristic theories which seek to provide ex post theoretical justifications of their findings, rather than ex ante theoretical constructs (Auci and Becchetti, 2006; Panayotou, 2000), and have focused on the impacts of only the income/growth variable, which captures the scale effects and in most cases, neglecting the composition and technique effects of economic development on the environment.

In line with these arguments, this study is an attempt to investigate the relationship between pollution emissions and economic development for an oil producing developing country, Nigeria, during the period 1960 to 2008. In addition to investigating the existence of the standard-EKC specification, the present study seeks to analyze the composition and technique effects of development on the environmental quality, by estimating nested-EKC models derived from the theoretical framework of emissions decomposition, developed by Stern (2002). What is more, the study seeks to analyze the stability and dynamic nature of the income-environment relationship in Nigeria. The latter objective is achieved by means of inter-decadal analysis of the econometric models.

What makes Nigeria a special case-study for the income-environment relationship? First, the structure of the Nigerian economy over the years has been dominated by pollution-intensive sectors. For example, between 1973 and 2008, the share of crude oil and gas production in total GDP has ranged between 21.1 and 37.5%, whereas, output from the services sector (which is regarded as less polluting) for the same period has been between 6.7 and 16.2% (CBN Statistical Bulletin, 2009). Also, since 1961, Nigeria's Ecological Footprint Balance Sheet has consistently been on the deficit balance, although there has been improvements in recent years, as the balance for 2010 was 0.3, down from a deficit of 1.92 in 1964 (see Ecological Footprint Atlas, 2010). From the institutional perspective, environmental policies, such as air pollution management (especially gas flaring) are becoming a major national priority and a major component of environmental policies in Nigeria. All these country-specific factors are likely to have significant implications on the EKC relationship for Nigeria, hence a justification for this study.

The balance of the paper is organized as follows. Section 2 discusses the theory and the literature on the income-environment relationship. In Section 3, the econometric methodology adopted for the study is described. Particular emphasis is placed on the derivation of the nested-EKC models. Section 4 contains the results from the models and the discussion of the results. In Section 5, the policy implications of the results are examined while Section 6 contains the conclusion.

2. Theory and literature on the income-environment relationship

Concerns about the impacts of economic activities on the environmental can be traced back to the 19th century, when Rev. Thomas Malthus condemned poor relief programmes as detrimental to the environment and a threat to man's ability to feed future generations. Since then, the debate about the interrelationships between development and environmental quality has been dichotomized into two main camps: those espousing Malthus' 'limit to growth' hypothesis and those arguing that economic growth is actually the key to environmental and human prosperity (Raymond, 2004).

Recently a third camp (that lies in-between the first two) known as the 'Ecological Modernization Proponents' are beginning to gain ascendancy. Members of this camp argue that society can reconcile economic growth and environmental quality through political and scientific innovations. Another related camp that is emerging is the 'Cornucopians' or optimists, who believe that economic growth and environmental improvements can exist in harmony.

The underlying presumption in all these lines of thinking (except for the neo-Malthusians) is that environmental quality deteriorates in early stages of economic development and improves in the latter stages as income increases, thereby leading to an inverted-U shaped kind of relationship usually referred to as the Environmental Kuznets Curve[1] (EKC) because of its resemblance with the curve that Kuznets (1955) observed in his study of the relationship between income inequality and development. The EKC hypothesis is intended to represent a long-run relationship between environmental quality and economic growth. The process is such that, as economic development accelerates at the take off stage with the intensification of agriculture and resource extraction, the rate of resource depletion begins to exceed the rate of resource regeneration and waste generation increases in quantity and toxicity (Dinda, 2004). At

[1] It was Grossman and Krueger (1993) who first attached Kuznets name to the curve after observing its close resemblance with Kuznets' discovery of and inverted-U shaped relationship between income inequality and development.

higher levels of development, structural change towards resource intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technologies and higher environmental expenditures result in 'levelling-off' and gradual decline of environmental degradation. Therefore, as income moves beyond the EKC turning point, it is assumed that the transition to the era of improvements in environmental quality starts (Panayoutou, 1993; Arrow et al., 1995; Stern, 2004). In summary, the EKC hypothesis postulates that economic development progresses from a relatively 'clean' agrarian economy, to a 'dirty' industrial economy, and finally, to a clean knowledge and services based economy.

Economic growth can be linked with environmental quality through three different mechanisms: the scale effect, the composition effect, and the technique effect (Grossman and Krueger, 1995). The scale effect has to do with the quantity of output. Increasing output requires more input and thus more natural resources are used up in production processes. More output also implies more waste and emissions as by-products which also contributes to environmental degradation. Hence, the scale effect of output has a negative impact on the environment. However, through the composition effect, economic growth can have positive impacts on the environment. As income grows, the structure of the economy tends to shift from primary activities which are pollution-intensive to tertiary activities[2] which are environment friendly..

Technological progress is expected to have positive effects on environmental quality. Since economic growth leads to the replacement of obsolete and 'dirty' technologies with new and cleaner technologies, emissions and other by-products are reduced, thereby improving environmental quality. Put together, the overall effect of economic growth on environmental quality is negative at the initial stages of development as a result of the scale effect, but, these

[2] Primary activities are activities that mostly involve resource extraction and are energy intensive, whereas, tertiary activities are activities that are knowledge and service-intensive,.

negative effects are eventually compensated for by the positive impacts of the composition and technique effects that prevail at the latter stages of development.

Empirically, evidence for the EKC hypothesis is at best mixed (Galeotti et al., 2006; He and Richard, 2010). Traditional empirical specifications of EKC include an indicator of environmental quality as the dependent variable and the levels, square and cubed values of real per capita income as the explanatory variables. Because of measurement problems, different variables have been used in the literature to proxy environmental quality. These proxies can be classified according to three main categories: air quality (e.g. CO_2, SO_2, PM_{10}, CO, NO_x etc.), water quality (e.g. concentration of pathogens in water, amount of heavy metals[3] and toxic chemicals discharged in water, water oxygen regimes, etc.) and other environmental indicators (e.g. municipal waste, energy use, traffic volumes, urban sanitation and access to safe drinking water (see Dinda, 2004 for a comprehensive list).

While some empirical studies have found a linear and monotonic relationship between environmental quality and GDP per capita (Fodha and Zaughdoud, 2010; Akbostanci et al., 2009; Shafik and Bandyopadhyay, 1992), others have found an inverted-U shaped relationship (Grossman and Krueger, 1995; Coel et al., 1997; Galeotti et al., 2006) with turning points ranging from \$3,000 to \$60,000; indicating a possible delinking of environmental quality from economic growth. (He and Richard, 2010). Yet, another group of studies have found an *N*-shaped relationship (Friedl and Getzner, 2003; Martinez-Zarzoso and Bengochea-Marancho, 2004) which implies that any delinking of environmental quality from economic growth can only be temporary (He and Richard, 2010).

The discrepancies in the nature of the relationships found by these studies and their turning points can be attributed to several factors. In particular, the chosen functional form of the model matters in determining the shape of the curve and the turning points. For example, Holtz-Eakin

[3] Heavy metals include lead, cadmium, mercury, arsenic and nickel among others.

and Selden (1995) used a log-linear regression model and found an inverted-U shaped EKC for CO_2 emissions with turning point around \$8 million. However, when they used a levels model, they found a turning point of \$35,248.

Also, the inclusion of other explanatory and control variables in the model, greatly influences the nature of the relationship that maybe observed. Roca et al. (2001) concluded that the hypothesis of EKC seemed to be weakened once other control variables (apart from income) are introduced. An important control variable that has been emphasized by several authors is the role of energy prices. The intuition is that increasing levels of oil prices will cause substitution effect which will reduce the use of fossil fuels, and hence lead to environmental improvements.

Lopez and Miltra's (2000) theoretical postulation that, for any level of per capita income, the rent-seeking activities of government officials raises pollution levels above the social optimum is particularly relevant for a resource dependent economy like Nigeria with very high levels of institutional corruption. Also, according to the Hecksher-Ohlin theorem, several authors have emphasized the role of international trade in shaping the income-environment relation. There is theoretically no consensus on the expected direction and nature of the impact of trade on the environment. Rothman (1998) explains that what may appear to be an improvement in environmental quality as a result of trade may in reality be an indication of the increased ability of consumers to distance themselves from the environmental degradation associated with their consumption; an idea referred to as the pollution heaven hypothesis. Copeland and Taylor (2004) conducted an extensive survey on this issue, and though he acknowledges the links between trade, environment and regulation, he downplays the idea of the pollution heaven hypothesis on grounds of little empirical support.

Most of the studies on the EKC hypothesis have been conducted using cross-country and panel data time series. This has lead to the use of simple error component models, which amounts to making the assumption that the income-environment relationship is internationally homogenous. He and Richard (2010) identified this factor as a major cause of discrepancy in the observed relationship between studies. This trend has been criticised for many reasons. Dijkgraaf and Vollebergh (2005) investigated the assumption of heterogeneity among 24 OECD countries with datasets spanning from 1960 to 1997. They reject the homogeneity assumption across countries and challenge the 'poolability' of cross-country panel data into an EKC analysis. Attempts to relax this restriction by using random coefficient models where done by List and Gallet (1999) Koop and Tole (1999) and Halkos (2003), they all concluded that different countries appear to have different turning points and that the 'one-form-fits-all' EKC curves obtained with standard panel data techniques should be used with caution. More emphatically, Fodha and Zaghdoud (2010) caution that EKC results from panel data analysis are unrealistic and dangerous.

Stern et al. (1996) assert that the only utility that can be drawn from cross-country EKC studies is a descriptive statistic. According to them, it is clear that a more fruitful approach to the analysis of the relationship between economic growth and environmental impact will require the examination of the time-series data of a single country. This approach allows one to take into account, historical experiences specific to that country such as structural change, environmental policy regimes, development of trade relations and exogenous shocks such as oil prices. This recommendation is what has motivated this Nigeria-specific study of the income-environment relation.

Though there has been widespread rejection and criticism of the assumption of international homogeneity which underpins cross-country analysis of the EKC hypothesis, there are however few studies that have responded to these criticisms by focusing on particular countries. De Bruyn et al. (1998) estimated the EKC for four specific countries, namely the Netherlands, the U.K, USA and Western Germany using data from 1960 to 1993. Their analysis shows that the EKC is not generally fit for all countries, each country has its own technological, structural, energy price and economic growth paths, so the emissions situations should not be the same. In another study, He and Richard (2010) used parametric, semi-parametric and flexible non-linear models to investigate the relationship between CO_2 emissions per capita and GDP per capita for Canada between 1948 and 2004. They found little evidence in favour of the EKC for Canada, and conclude that the oil price shock of the 1970s has had an important impact on the progress towards less polluting technologies and production.

Friedl and Getzner (2003) explored the relationship between economic development and CO_2 emissions in Australia between 1960 and 1999, and observed an *N*-shaped relationship between GDP and CO_2 with a structural break identified in the mid-seventies due to oil price shocks. Fodha and Zaghdoud (2010) investigate the existence of the EKC relation for Tunisia using CO_2 and SO_2 emissions for the period 1961-2004. They find long-run cointegration between GDP per capita and their proxies for environmental quality. Specifically, they find an inverted-U shaped relation with a turning point of $1,200 for SO_2. Using the CO_2 proxy, their results reveal the existence of a monotonically increasing relationship between CO_2 emissions and GDP. They also carried out causality tests, which showed that the relationship between income and environment is unidirectional, with income causing the environment.

Akbostanci et al. (2009) used cointegration techniques to examine the income – environment relation for Turkey. Both time series and provincial panel data analysis were conducted between the periods of 1968 to 2003 and 1992 to 2001 respectively. They found a monotonically increasing relationship between CO_2 emissions and income in the times series analysis. On the other hand, their panel data analysis indicated an *N*-shaped relationship for SO_2 and PM_{10} emissions.

EKC studies for Nigeria are rare. To the best of my knowledge, there are only two studies that investigate the EKC hypothesis for Nigeria. Bello and Abimbola (2010) studied the EKC hypothesis in Nigeria using a standard EKC model with four control variables: foreign direct investments (FDI), share of manufacturing in GDP, energy consumption and a financial sector variable. They found no evidence of the EKC relation; rather they obtained a U-shaped relation between CO_2 emissions and GDP growth rate in Nigeria. Olusegun (2009) investigates the EKC hypothesis in Nigeria with annual data of CO2 per capita and GDP per capita from 1970-2005. His study reveals that there is no causal or long-run relationship between CO2 per capita and GDP per capita. Interestingly, he obtains a U-shaped curve, rather than an inverted-U shaped relationship.

Though these reviewed studies have focused on country-specific EKC relationships, they however do not incorporate variables that could capture the composition effect (input and output mix) and the technology effects of development on the environment. Also, the stability or instability of the observed relationships over time is another useful aspect of the relationship that has not been considered by most of these studies.

For these reasons and others, the present paper investigates the income-environment relationship for a single oil-exporting economy; Nigeria, over a 48 year time horizon (1960-2008) with inter-decadal analysis of 20-year rolling periods for dynamics and stability insights. Moreover, taking into account the theoretical predictions of the EKC relation, we depart from the traditional specification and estimate a nested-EKC model with appropriate decompositions to help examine the composition effects represented by the input mix and output mix variables as developed and tested by Stern (2002).

3.0 Methodology

3.1. The standard EKC Model

To determine the nature of the relationship between environmental quality and economic development in Nigeria, we draw from both the EKC and the original Kuznets curve literature (see Kuznets, 1955; Barro, 2000; Caviglia-Harris et al., 2009; Shafik and Bandyopadhyay, 1992). The underlying hypothesis is that the relationship between economic growth and environmental quality is not monotonic and may change direction from upward to downward when a country reaches a level of development (income) at which people prefer a cleaner environment to higher levels of income. This implies an inverted U-shaped relationship between environmental quality and income.

Three different functional forms are commonly used to examine this relationship: a linear function (which implies a monotonic relationship), a quadratic function (which implies an inverted-U shaped relationship) and a cubic function (which will imply an *N*-shaped or a sideways mirrored *S*-shaped relationship).

Typically, the standard EKC model takes the following form.

$$\left(\frac{E}{P}\right)_t = \alpha_0 + \alpha_1 t + \beta_1\left(\frac{GDP}{P}\right)_t + \beta_2\left(\frac{GDP}{P}\right)_t^2 + \beta_3\left(\frac{GDP}{P}\right)_t^3 + \gamma X_t + \mu_t \qquad (1)$$

Where E is environmental degradation captured by CO_2 emissions, P is population size, hence (E/P) is per capita CO_2 emissions. (GDP/P) is per capita real GDP and X_t is a vector of variables that may often affect environmental quality. t is the deterministic time trend, used as a crude proxy for technological progress. For various reasons, mainly data availability and/or small sample sizes, several empirical studies entirely omit the vector X_t. We also follow this approach for the reasons given above[4]. Thus we place the restriction that $\gamma = 0$. With this, we can describe the relationship that may be expected to hold between income and the environment with varying signs of β_i. If $\beta_1 > 0$, and $\beta_2 = \beta_3 = 0$, then, we have the linear case where the relationship between economic development and environmental quality is monotonically increasing.

[4] He and Richard (2010) caution that this may lead to biased and inconsistent inferences about the parameter estimates

If $\beta_1 > 0$, $\beta_2 < 0$, and $\beta_3 = 0$, then there will be an inverted-U shaped relationship between emissions and GDP. Finally, if $\beta_1 > 0$, $\beta_2 < 0$, and $\beta_3 > 0$, then an *N*-shaped relationship between emissions per capita and output per capita will be observed. Conversely, Friedl and Getzner (2003) show that if these signs are reversed (i.e., $\beta_1 < 0$, $\beta_2 > 0$, and $\beta_3 < 0$), then a sideways mirrored *S*-shaped graph will be observed[5]. From these specifications, the turning point income per capita for which per capita emissions are at their maximum levels is easily derived as:

$$\left(\frac{GDP}{P}\right)_{max} = \left(\frac{-\beta_1}{2\beta_2}\right) \tag{2}$$

Where β_1 and β_2 are the parameter estimates for the levels and square of per capita GDP respectively.

3.2. Nested-EKC decomposition model

In carrying out investigations about the existence and nature of the EKC relation for a particular country, it is useful to also consider nested and decomposed models of the standard specification in other to gain insights into the composition (input and output mix) and technique effects growth on the environment. We say that a model 'A' is nested in another model 'B' if it contains most of the regressors in 'B' and perhaps with further decomposition (see Gujarati and Porter, 2009: 449). The first set of authors that used a nested-EKC model to examine the interrelationships between emissions and income focused on three effects: scale, composition and abatement effects (see, Panayotou, 1997; Islam et al., 1999). Their decomposition of these effects were based on Grossman and Kreuger (1995) and De Bruyn's (1997) framework for decomposing pollution emissions. Thus pollution emissions for a country can be decomposed according to the following identity.

[5] For other possible forms of relationship, see Dinda (2004) and Stern, (2004)

$$E_{it} = \sum_{j=1}^{n} Y_t (E_{jt}/Y_{jt})(Y_{jt}/Y_t) \;\; or$$

$$E_{it} = \sum_{j=1}^{n} Y_{it}\, I_{ijt}\, S_{ijt} \tag{3}$$

Where E_t represents emissions from sector j (j= 1, . . ., n) at time *t*, Y_t is GDP, Y_{jt} is individual sectors' GDP or value added, $E_{jt}/Y_{jt} = I_{jt}$ is the emissions intensity of sector *j*, and $Y_{jt}/Y_t) = S_{jt}$ is the share of sector *j* in GDP. Though comprehensive, this decomposition model has two main limitations. First, it does not consider the effects of technological changes and the dynamics of the input mix used in production (see Auci and Becchetti, 2006). Second, the model is difficult to estimate in practise, since data on emissions at the industry level are generally not available (Stern, 2002).

For these reasons and others, Stern (2002) developed a more practicable and estimatable framework for decomposition, in which he nests the standard-EKC model. Thus, we derive our nested-EKC model from the decomposed framework presented by Stern (2002)[6] who considers emissions from the *i* th country, as depending on factors, thus:

$$E_{it} = f_i(y_{it}, x_{it}, A_t) \tag{4}$$

Where E_{it} is the total emission of carbon dioxide , y_{it} is a vector of *J* outputs, x_{it} is a vector of *K* inputs, and A_t is the state of technology. By assuming that $f_i(.)$ is homogenous of degree one, in inputs, and homogenous of degree zero in outputs, we obtain

$$\frac{E_{it}}{P_{it}} = \gamma_i \frac{A_t}{TFP_{it}}\, b_{it} \frac{Y_{it}}{P_{it}} \left(\frac{y_{it}}{Y_{it}}\right)^{-\sum_{j=1}^{J-1} \alpha_j} \prod_{k=1}^{J-1} \left(\frac{y_{it}}{Y_{it}}\right)^{\alpha_j} \sum_{k=1}^{K} \beta_k \frac{x_{it}}{X_{it}} \epsilon_{it} \tag{5}$$

Where Y_{it}/P_{it} represents the scale effect, A_t represents the state of technology, b_{it} is the abatement effect, $1/TFP_{it}$ is the overall technological progress and $(y_{1it}/Y_{it})\ .\ .\ .\ (y_{jit}/Y_{it})$ and

[6] This framework has been applied by Auci and Becchetti (2006) for a panel of 173 countries.

$(x_{1it}/X_{it}) \dots (x_{jit}/X_{it})$ represents the output and input mix respectively. Taking the logarithms and nesting the standard-EKC model,

$$\ln(E_{it}/P_{it}) = \ln(\gamma_i) + \delta_0 \ln(A_t) + \delta_1 \ln(TFP_{it}) + \delta_2 \ln(Y_{it}/P_{it}) + \delta_3 \ln(b_{it}) + \sum_{j=1}^{J} \alpha_j \ln\left(\frac{y_{it}}{Y_{it}}\right)$$
$$+ ln\left(\gamma_1 \sum_{k=1}^{K} \beta_k \frac{x_{it}}{X_{it}}\right) + \delta_2 \ln(Y_{it}/P_{it})^2 + v_{it} \qquad (6)$$

By abstracting from the theoretical model of Stern (2002), we specify a nested-EKC model which takes into consideration the scale, output and input mix and state of technology effects. Hence, our nested-EKC model in econometric form is presented thus:

$$E_t = \alpha_0 + \alpha_1 t + \beta_1 (GDPpc)_t + \beta_2 (GDPpc)_t^2 + \beta_3 (GDPpc)_t^3 + \beta_4 CPG_t + \beta_5 SM_t$$
$$+ \beta_6 MAN_t + \beta_7 AGR_t + \beta_8 SERV_t + \epsilon_t \qquad (7)$$

Where E_t is per capita emissions of carbon dioxide (i.e., *CO_2/P*), t is a linear time trend which serves as a crude proxy for technological developments, $GDPpc$ is GDP per capita, CPG and SM represents the shares of crude petroleum and natural gas and solid minerals in GDP respectively. They are both used to capture the input effect. MAN, AGR, and $SERV$ represents the shares of manufacturing, agric and the services sectors in GDP respectively[7]. These variables are used to capture the output mix, while ϵ_t is the random error term. The models (standard-EKC and nested-EKC) are estimated for the entire sample period 1960-2008, and at different rolling decades of 20 years each[8].

3.3 Data measurement and diagnostics

[7] Auci and Becchetti (2006) used slightly different measures. For example their input variables in their adjusted-EKC model where the shares of coal, gas and oil used in electricity generation.
[8] Except for the last decadal fragment which is for 18 years.

To carry out the analysis on the development-environment relation in Nigeria, this study employs time series data on Nigeria from 1960 to 2008. We use CO_2 emissions per capita as the relevant measure of environmental degradation[9]. This variable is measured in metric tons, and it comprises of emissions stemming from the burning of fossil fuels, and the manufacture of cement. Specifically, it includes the contributions of carbon-dioxide produced during consumption of solid, liquid and gas fuels, including gas flaring. The data set is obtained from the World Bank-World Development Indicators(WDI). Our measure for development is per capita GDP at 1990 PPP. The series are obtained from the World Bank-World Development Indicators(WDI).

Crude petroleum and natural gas in GDP is obtained from the Abstract of the National Bureau of Statistics (NBS) (various issues). Solid minerals in GDP comprises of coal mining, metal ores, quarrying and other mining in GDP. It is extracted from the annual abstracts of the NBS. The share of manufacturing in GDP has three major components: oil refining, cement and other manufacturing. Agric includes output from crop production, livestock, forestry and fishing. While the services sector include transport, communication and other utilities (e.g. electricity). All these series are obtained from the CBN Statistical Bulletin (2009).

Table 1 displays the summary statistics of the variables used in the study, and Figure 1 shows the evolution of GDP per capita (*GDPpc)* and CO_2 emissions per capita (*E*) in Nigeria. From Table 1, it can be observed that the agricultural sector has the highest share in GDP with a mean value of 61,661.08 followed by crude petroleum and natural gas with a mean of 53,835.36. The substantial share of these two sectors in GDP is an indication that the economic (production) structure in Nigeria is pollution-intensive. Further, it can be observed that the solid minerals sector may not be an important source of pollution, given its relatively low contribution to GDP.

[9] Some authors have argued that CO_2 emissions are global pollutants, and therefore it may not be appropriate for country or region-specific studies. However, because time series data for local pollutants like SO_4 are not readily available, we suffice with CO_2 emissions per capita which has also been used for numerous country specific studies, see for e.g. He and Richard (2010).

The mean value of the services sector (which includes transportation and electricity generation) indicates that it is a major contributor to GDP and hence, pollution.

Table 1. Descriptive Statistics

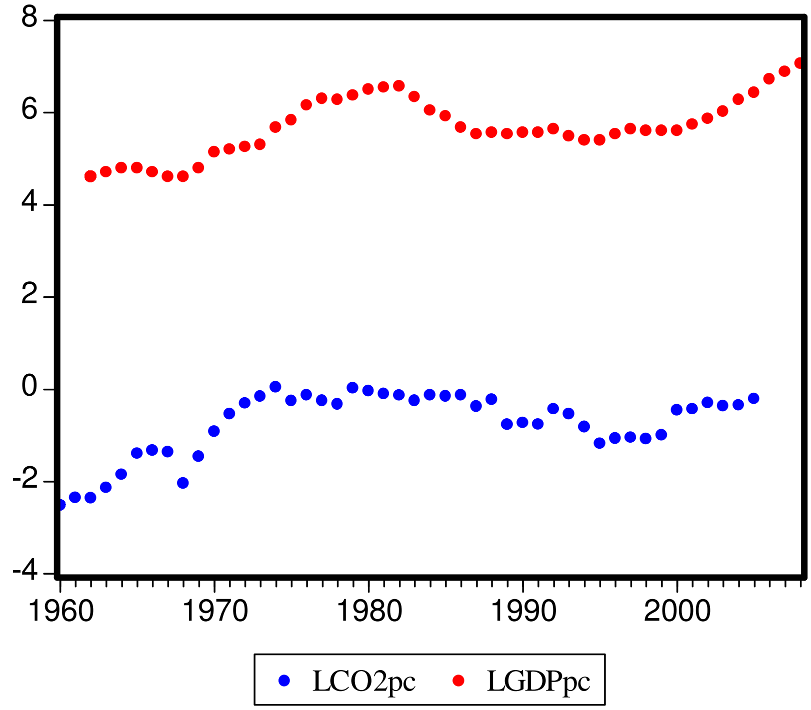
	AGR	CO_2	CPG	GDPpc	MAN	SERV	SM
Mean	61661.08	0.588168	53835.36	315.2273	8575.934	21177.85	697.1386
Median	59230.15	0.647143	67949.55	270.0000	11807.50	19165.25	685.6500
Max.	231463.6	1.043542	136345.5	710.0000	21305.10	85478.80	2245.200
Min.	1338.000	0.094158	29.00000	100.0000	146.4000	346.7000	24.00000
S.D.	63774.91	0.269700	48146.87	173.2788	7065.073	22297.37	566.2236
Skw.	0.973476	-0.25193	0.068146	0.774741	-0.072391	1.187766	0.819071
Kurtosis	3.374006	1.863963	1.440974	2.605549	1.361488	3.902225	3.604416
J.B	7.205916	2.831505	4.490085	4.686889	4.960420	11.83812	5.589523
Prob.	0.027243	0.242743	0.105923	0.095996	0.083726	0.002688	0.061129
Obs.	44	44	44	44	44	44	44

The evolution of GDP per capita and emissions per capita, as displayed in Figure 1[10], shows that as time passes by, and GPPpc increases, the gap between the two series tends to slightly widen. This pattern suggests that the trend of emissions intensity in Nigeria may have been fairly constant (or even reducing). This can be interpreted as preliminary evidence of the existence of the EKC hypothesis for CO_2pc in Nigeria. Nevertheless, it can be misleading to rely on visual analysis of evolution patterns to arrive at conclusions, as several factors besides GDPpc may affect CO_2pc . He and Richard (2010), Lindmark (2002) and Moomau and Unruh (1997) and Dinda (2004) have emphasized some of these other factors[11].

[10] The evolution of CO_2 per capita and GDP per capita are transformed to their natural logarithms, to aid visual comparison.

[11] Some of the other factors that have been considered in the literature include, globalization, regulation, market mechanism and corruption (see Dinda, 2004).

Figure 1. Evolution of GDPpc and CO_2pc (1960-2008)



Before proceeding with the econometric analysis, it is crucial to first perform diagnostic tests of integration and cointegration on all the series, to determine the nature in which the variables will enter the model, and to avoid the likelihood of obtaining spurious regressions. Hence, we test for stationarity in the time series, using two different procedures: the Augmented Dickey Fuller test (Dickey and Fuller, 1974), and the Kwiatkowiski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowiski et al., 1992). The use of the KPSS test here, is to complement the widely employed ADF test since this test (KPSS) is designed to overcome the problems of low power and size distortions, inherent in the ADF test (see Chuku, 2009).

Following the conclusions from the stationarity tests, we investigate the possibility of cointegration among the variables. We follow the Johansen technique (Johansen, 1995), which involves determining the rank of the impact matrix, i.e. the long-run matrix. The rank gives the number of linearly independent columns of the long-run matrix which represents the number if cointegrating relationships that exist among the variables. Two test statistics are employed in arriving at conclusions: the trace statistic and the maximum eigen value statistic. The trace statistic is used to tests the null hypothesis that $r = k$ (where k= 1, 2, . .., n-1), against the alternative of unrestricted r. While the maximum eigenvalue tests that there are r cointegrating vectors, against the alternative which states that there are $r + 1$ cointegrating vectors. The Schwarz Information Criterion is used to select the appropriate trend and intercept specification for the test.

4. Results and Analysis

4.1. Integration results

Table 2 presents the results of the integration tests conducted on all the variables. The ADF test results reveal that all the variables have unit roots in their times series dimension, i.e., they are non-stationary in their levels. However, all the series became stationary after taking their first differences. Hence, we conclude that all the seiers are $I(1)$ stationary. Our conclusions are validated by the KPSS stationarity test, since the results lead to the rejection of the null hypothesis of stationarity in the levels of all the variables. Whereas, after taking the first differences, we are unable to reject the null hypothesis of stationarity for all the variables.

Table 2. Unit Root and stationarity Tests

	ADF		KPSS		
Variable	**Level**	**1st Difference**	**Level**	**1st Difference**	**Conclusion**
CO2	-1.91(0)	-7.16(0)***	0.44(5)*	0.14(2)	*I*(1)
GDPpc	-0.22(1)	-2.73(0)*	0.38(5)*	0.24(4)	*I*(1)
CPG	0.53(0)	-6.02(1)***	0.87(5)***	0.19(3)	*I*(1)
SM	-1.51(1)	-5.33(0)***	0.61(5)***	0.08(3)	*I*(1)
MAN	-0.67(0)	-7.76(0)***	0.89(5)***	0.10(4)	*I*(1)
AGR	2.02(0)	-5.69(0)***	0.82(5)***	0.24(22)	*I*(1)
SERV	0.33(0)	-4.32(0)***	0.81(5)***	0.26(4)	*I*(1)

Notes: ***,** and * indicates significance at the 1%, 5%, 10% levels respectively. The values in bracket for the ADF test indicates the optimal lag length selected by the SIC within a maximum lag of 13. The values in bracket for the KPSS test indicates the bandwidth selection, using the Newey-West's Bartlett Kernel criterion

These conclusions imply that estimating equations (1) and (7) in levels might lead to spurious regressions, unless the variables share a common stochastic trend. (i.e. unless they are cointegrated). Hence, we proceed with tests of cointegration using the Johansen (1995) approach.

4.2. Cointegration results

The results from the Johansen cointegration test for the Standard-EKC model and the Nested-EKC model are presented in Tables 3 and 4 respectively. The test assumption used allows for a linear deterministic trend in the time series and an intercept in the cointegrating equation. Further, since the Johansen (1995) approach is sensitive to the lag length used, we used the optimal lag length of one, selected by the Schwarz Information Criterion (SIC).

In Table 3, we observe that both the trace and max-eigenvalue tests indicate that at the 5% level of significance, there is one coinitegrated relationship in the standard-EKC model. This implies that there is a long-run equilibrium relationship between CO_2 emissions per capita and

GDP per capita at levels, squared and cube in Nigeria. These results give the assurance that the standard-EKC model can be estimated with the variables at the levels.

Similar results are also observed for the cointegration test of the nested-EKC model. Table 4 reveals that there is cointegration between CO_2 emissions per capita and the decomposed series in the nested model. The results however, indicate that there is a controversy about the number of cointegrating equations present, as the trace test reports that there are seven cointegrating equations, while the maximum eigenvalue reports that there are three cointegrationg equations. We do not pursue this controversy further, as our primary concern is to ascertain that there is cointegration among the variables. Again, these results imply that it is safe to estimate the nested-EKC model with the variables in their levels without obtaining spurious results.

Table 3. Johansen Cointegration test for Standard-EKC Model

Null Hypothesis	Alt. Hypothesis	Test Statistic	Critical Value (5%)	P-Value
		Trace test		
r = 0	r = < 1	52.41	47.85	0.01
r = 1	r = < 2	22.84	29.79	0.25
r = 2	r = < 3	7.41	15.49	0.53
r = 3	r = < 4	2.41	3.84	0.12
		Maximum Eigenvalue test		
r = 0	r = 1	29.57	27.58	0.02
r = 1	r = 2	15.42	21.13	0.26
r = 2	r = 3	5.00	14.26	0.74
r = 3	r = 4	2.41	3.84	0.12

Table 4. Johansen Cointegration test for Nested-EKC Model

Null Hypothesis	Alt. Hypothesis	Test Statistic	Critical Value (5%)	P-Value
		Trace test		
r = 0	r = < 1	371.25	197.37	0.00
r = 1	r = < 2	260.28	159.52	0.00
r = 2	r = < 3	178.74	125.61	0.00
r = 3	r = < 4	115.21	95.51	0.00
r = 4	r = < 5	77.68	69.81	0.01
r = 5	r = < 6	52.39	47.85	0.01
r = 6	r = < 7	30.99	29.79	0.03
r = 7	r = < 8	12.61	15.49	0.12
r = 8	r = < 9	2.38	3.84	0.12
		Maximum Eigenvalue test		
r = 0	r = 1	110.96	58.43	0.00
r = 1	r = 2	81.53	52.36	0.00
r = 2	r = 3	63.53	46.23	0.00
r = 3	r = 4	37.52	40.07	0.09
r = 4	r = 5	25.29	33.87	0.36
r = 5	r = 6	21.40	27.58	0.25
r = 6	r = 7	18.37	21.13	0.11
r = 7	r = 8	10.23	14.26	0.19
r = 8	r = 9	2.38	3.84	0.12

4.3. Results from the standard- and nested-EKC models.

Table 5 presents the estimated results of the standard and nested-EKC models for Nigeria. The parameter estimates from the standard-EKC model (Table 5, column 2) seems to support, at least weakly, the EKC hypothesis for Nigeria. This is because the parameters β_1, β_2, and β_3 assumed positive, negative and positive signs respectively. The interpretation of this result as weak evidence of the EKC is informed by the statistical insignificance of the β_3 parameter, even at the 10% nominal level. Thus, we are unable to reject the hypothesis that $\beta_3 = 0$. Hence, using the standard-EKC model we conclude that the relationship between development and emissions in Nigeria follows an inverted-U shape, with a turning point around $280.84. The fitted curve using the standard model is depicted in Figure 2.

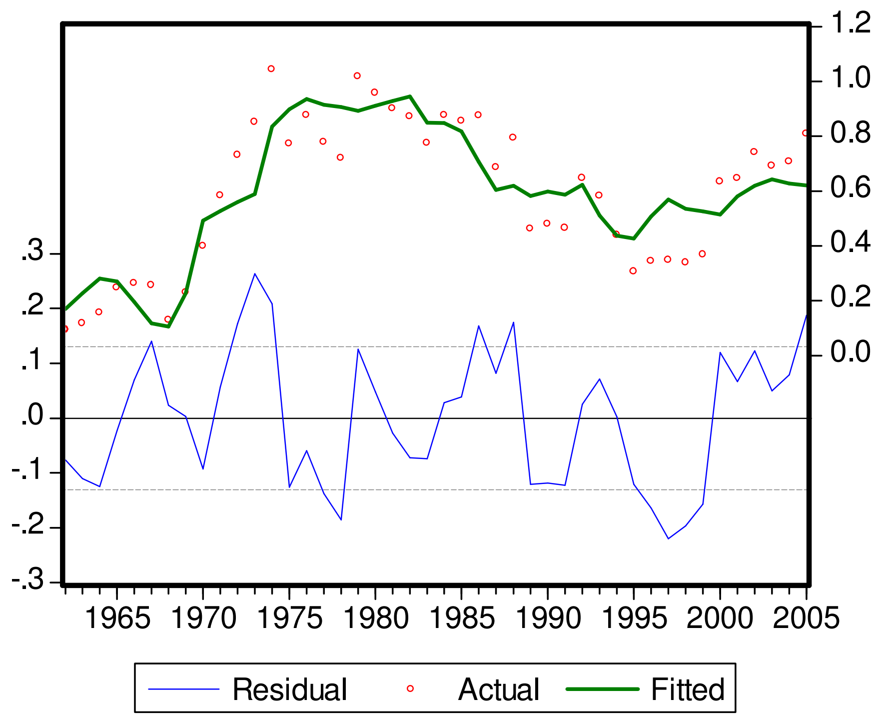
Table 5. Estimates of the Standard - and Nested EKC Models

Dependant Variable CO_2 per capita		
	Standard- EKC	**Nested-EKC**
Constant	-0.3018	-0.7869
	(0.1862)	(0.1914)
t	-0.0107***	-0.0135
	(0.0023)	(0.0084)
GDPpc	0.0056***	0.0112***
	(0.0018)	(0.0021)
GDPpc^2	-9.97E-06*	-2.36E-05***
	(-0.56E-06)	(-6.10E-06)
GDPpc^3	6.24E-09	1.60E-08***
	(4.87E-09)	(5.26E-09)
CPG		9.58E-06***
		(3.47E-06)
SM		6.53E-06
		(-0.0001)
MAN		2.82E-05
		(2.04E-05)
AGR		1.94E-06
		(3.05E-06)
SERV		1.07E-06
		(7.07E-06)
R^2 Adj.	0.6478	0.7825
ARCH (2 lags)	0.85 (0.6676)	13.41 (0.000)
RESET (2 terms)	0.61 (0.5517)	7.62 (0.0018)
Chow (1973)	1.08 (0.3801)	0.42 (0.9102)
Chow (1986)	5.91 (0.0009)	1.47 (0.2083)
T.P	280.84	237.28

Notes: ***, ** and * denotes asymptotic significance at the 1%, 5%, and 10% levels respectively. Values in brackets represent standard errors for parameters and p-values for the relevant test statistic.

Economic common sense and specification tests reported at the bottom of Table 5: column 2, evidently suggests the under-specification of the model, as shown by the RESET test, and makes the robustness of the results highly questionable. Also, the non-rejection of the test that there is no autoregressive conditional heteroscedasticity (ARCH) implies that the error variances from the regression are related to the squared error term in the previous period, and therefore would have led to some sort of efficiency losses (see Gujarati and Porter, 2009). It is this observed mis-specification in the standard-EKC model and the need to also examine the composition effects of economic growth on emissions in Nigeria that has motivated the estimation of a nested-EKC model for Nigeria.

Figure 2. Fitted curve of Standard-EKC model



Column 3 of Table 5, contains the results from the nested-EKC model. Again, we observe that the signs of the income parameters, assumed the hypothesized signs, i.e. $\beta_1 > 0$, $\beta_2 < 0$, and $\beta_3 > 0$. However, unlike the standard-EKC model, the nested model presents strong[12] evidence of an *N*-shaped relationship between income and emissions in Nigeria. Figure 3, shows the fitted relationship, which is *N*-shaped. We observe that the fitted relationship using the nested model (Figure 3) is smoother than the fitted relationship using the standard- model, an

[12] We conclude that the evidence here is strong because the three parameter estimates fro the income variable are statistically significant, and specification tests of the model are supportive.

intuitive indication that the nested-EKC model better captures the relationship between income and emissions in Nigeria.

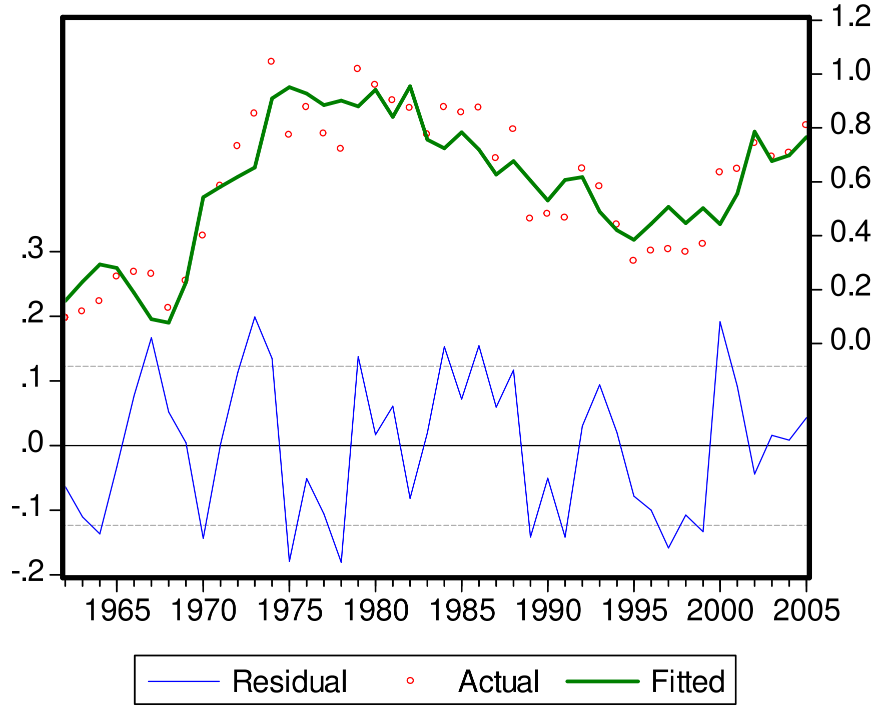
Moving to the composition effect, we observe that the parameter estimates of the input variables (crude petroleum and natural gas in GDP and solid minerals in GDP) both assumed positive signs, an aberration from the usual. Input variables have often been found to carry negative signs for most advanced economies (see Agras and Chapman, 1999; Heil and Selden, 2001; He and Richard, 2010) which is usually attributed to the technique-effect. The positive signs found in Nigeria is suggestive that production activities in the extractive industries in Nigeria may not have adopted emissions-(environment) friendly technologies over the years. This interpretation is confirmed by the negative but insignificant value of the parameter estimate of the time trend, which implies that technological progress decreases per capita emissions in Nigeria.

Similarly, the parameter estimates of the output variables assumed positive signs, though none was statistically significant. This again may be suggestive that the manufacturing, agric and services sectors in Nigeria have generally been pollution-intensive with no significant movements towards less polluting techniques.

At \$237.28, the maximum value (turning point) of GDP per capita for the nested-EKC model is slightly lower than that of the standard model. The nested model provides a better-fit of the relationship between GDPpc and CO_2pc. This is observed in the higher adjusted r-squared value of 0.78 compared with 0.64 obtained in the standard model.

Specification tests for the nested model reveals that the model is correctly specified (see ARCH and RESET test). Also, the hypothesis that there is no structural break caused by the oil price increase of 1973 and the structural adjustment programme (SAP) in 1986 cannot be rejected. Hence, the 1973 oil price shock and changes in the structure of the Nigerian economy as a result of the implementation of SAP have both not affected the relationship between income and emissions in Nigeria.

Figure 3. Fitted curve of Nested-EKC model



4.4 Inter-decadal analysis

The *N*-shaped results obtained in the nested-EKC model, may be seen to represent the relationship that exists between income and emissions in the long-time horizon. To investigate the dynamics and the stability of this observed relationship, we defragment the entire sample period into four rolling decades of 20-years each[13] and re-estimate the standard- and nested-EKC models. The results are presented in Table 6.

The rolling estimates of the standard- and nested- models for different sample fragments clearly indicates that the observed *N*-shaped relationship is stable over time and insensitive to the sample interval chosen. This is because the three parameter estimates for GDPpc at levels,

[13] The last fragment however contains 18 years.

squares and cubed assumed positive, negative and positive signs respectively. The general conclusion we make from this robustness analysis is that the standard- and nested-EKC specifications for Nigeria is *N*-shaped irrespective of the chosen time-interval and estimation period.

Another relevant finding from the inter-decadal analysis is that the turning points do not seem to show any systematic form of progression or retrogression. This may be due to the falling and rising nature of the squared GDPpc coefficient. We also observed that the coefficients of the input and output variables assumed varying signs and most of them are statistically insignificant. These outcomes could be as a result of the limited number of observations available in the fragments.

Table 6. Results from Inter-decadal Estimates

Dependant Variable CO_2 emissions per capita

	1960-1980		1970-1990		1980-2000		1990-2008	
	Std- EKC	**Nstd-EKC**	**Std- EKC**	**Nstd-EKC**	**Std- EKC**	**Nstd-EKC**	**Std- EKC**	**Nstd-EKC**
Constant	-1.02111***	-0.6887***	-0.2167	-1.1259*	-1.4498	-1.1215	-1.0213	-4.1653*
	(-0.2034)	(0.1924)	(0.5895)	(0.6353)	(-1.3041)	(1.2509)	(1.3841)	(-2.1807)
t	0.0239	0.0108	-0.0145**	0.0271	-0.0255***	-0.0785	-0.0061	-0.0710
	(0.0151)	(0.0205)	(0.0062)	(0.0312)	(0.0064)	(0.0657)	(0.0112)	(0.0732)
GDPpc	0.01456***	0.0151***	0.0065	0.0151**	0.0126	0.0152	0.0097	0.0173
	(0.0023)	(0.0002)	(0.0047)	(0.0055)	(0.0098)	(0.0109)	(0.0112)	(0.0112)
GDPpc^2	-3.52E-05***	-4.36E-05***	-1.32E-05	-3.28E-05**	-2.29E-05	-3.34E-05	-1.86E-05	-4.70E-05
	(0.0002)	(9.65E-06)	(1.17E-05)	(1.45E-05)	(2.33E-05)	(2.73E-05)	(2.91E-05)	(3.20E-05)
GDPpc^3	2.69E-08***	3.60E-08***	8.89E-09	2.30E-08*	1.38E-08	2.28E-08	1.22E-08	3.45E-08
	(6.67E-09)	(1.13E-08)	(8.88E-09)	(1.20E-08)	(1.70E-08)	(2.01E-08)	(2.37E-08)	(2.69E-08)
CPG		0.0001**		1.29E-05		-3.45E-06		2.41E-06
		(6.22E-05)		(8.84E-06)		(7.33E-06)		(6.86E-06)
SM		0.002		6.67E-05		0.0001		0.0007
		(0.0005)		(0.0001)		(0.001)		(0.0011)
MAN		-7.86E-05		8.47E-06		5.61E-06		0.0001*
		(0.0002)		(7.05E-05)		(3.02E-05)		(6.72E-05)
AGR		-0.0002**		9.22E-06		2.98E-06		-1.16E-06
		(0.0001)		(1.34E-05)		(9.52E-06)		(3.08E-06)
SERV		0.0001		-0.0001***		-1.97E-05		-1.50E-06
		(0.0002)		(4.04E-05)		(2.62E-05)		(1.61E-05)
R^2 Adj.	0.8890	0.9499	0.3798	0.5300	0.5235	0.6860	0.4886	0.5745
ARCH	2.01 (0.1704)	0.03 (0.9611)	4.12 (0.0358)	1.24 (0.3145)	1.33 (0.2920)	0.03 (0.9681)	2.14 (0.1631)	1.88 (0.1980)
RESET	2.04 (0.1690)	5.00 (0.0388)	0.13 (0.8787)	0.9 (0.4145)	0.10 (0.9037)	2.02 (0.1824)	0.41 (0.6707)	1.23 (0.3672)
T.P	206.81	173.16	246.21	266.97	275.10	227.54	241.93	216.25

Notes: ***, ** and * denotes asymptotic significance at the 1%, 5%, and 10% levels respectively. Values in brackets represent standard errors for parameters and p-values for the relevant test statistic.

5. Policy implications

The observed *N*-shaped relationship between income and environment in Nigeria has two-pronged policy implications. On the one hand, it implies that economic growth is compatible with environmental improvements in Nigeria. That is, Nigeria can grow its way economically out of its environmental problems. This recommendation emerges from the first two-strands of the *N*-shape. The last two-strands of the *N* implies that without some form of non-income intervention, environmental degradation will begin to increase again, after a certain threshold. Hence, the need for intensified environmental preservation policies. This need is reinforced by the finding from the nested-models that the input and output components of GDP in Nigeria have increasingly been pollution-intensive, this may be an indication of weak diffusion of environment-friendly inputs and techniques in Nigeria's production systems.

Though environmental regulations in Nigeria have generally been weak, it can be strengthened by following a few basic principles. The first will be to keep environmental policies focused. This is necessary because it is know that the major source of environmental degradation and air pollution in Nigeria is from oil exploration activities (NNPC, 2007). Emissions can be significantly reduced by targeting regulatory monitoring of the oil and gas sectors. Also, regulatory agencies may begin to consider moving away from command-and-control strategies towards market oriented forms of regulation. The use of pervasive informal regulation should also be adopted, as it has been proven to be effective in other developing economies (Dasgupta et al., 2002; Dinda, 2004; Raymond, 2004).

6. Conclusion

Recent surveys on the theoretical and empirical literature on the income-environment relationship emphasize the need to move from the 'one-form-fits-all' cross-country analysis to country specific analysis. Also, the often not theoretically grounded standard-EKC specification in which per capita income in levels, squares and cubed, are the only variables considered to affect environmental degradation have been criticized for their inability to take into full account, supply and demand side factors, such as scale effects, composition effects and technique effects (Stern, 2004; Copeland et al., 2004).

To this end, the present study investigates the income-environment relation for an oil-producing economy, Nigeria, between 1960 and 2008. Standard- and nested (decomposed)-EKC models are estimated to examine this relationship in Nigeria. CO_2 emissions per capita is used as the proxy for environmental quality, while GDP per capita, measure the progress of development. The nested-EKC model is derived from an emissions decomposition framework in which input and output components of GDP are differentiated.

Before estimating the models, tests of integration and cointegration are performed on all the series. The integration results show that all the variables are $I(1)$ stationary. This result necessitated the tests for long-run cointegration among the variables in the two sets of models. The test using the Johansen procedure provides evidence that suggests the existence of a long-run stochastic trend among the variables.

Results obtained from the standard-EKC specification is somewhat ambiguous, though the signs of the income parameter suggest an *N*-shaped relationship, we interpret it to be weak evidence of the existence of EKC. Our interpretation is informed by the statistical insignificance of the income cubed variable. Moving to the nested-EKC model, we find strong evidence that suggests and *N*-shaped relationship between income and CO_2 emissions with a turning point at $237.28. Results from the inter-decadal analysis shows that the observed relationship is stable over time and insensitive to the sample interval chosen. Tests about no structural breaks caused by the 1973 oil price shocks and 1986 Structural Adjustment programme (SAP) are not rejected, implying that these factors have not significantly affected the income-environment relationship in Nigeria.

Overall, our findings imply that economic development is compatible with environmental improvements in Nigeria. However, tighter and concentrated environmental policy regimes will be required to ensure that the relationship is maintained around the first two-strands of the *N*-shape.

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