

Assessment of the Validity of the Environmental Kuznets Curve (EKC) Hypothesis in the Nigerian Economy.

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ABSTRACT: The Environmental Kuznets Curve (EKC) hypothesis is a theory based on income inequality and economic growth/development. It seeks to identify the relationship between different indicators of environmental pollution and per capita income. The theory suggests that environmental quality decreases in early periods of economic growth; but after a certain level of economic advancement, the economy begins to experience environmental quality increase. This study is carried out to confirm whether the EKC theory is applicable in Nigerian economy. The study employed quarterly time series data ranging from 1992 – 2024. For analysis the vector error correction model (VECM) and causality estimation techniques among others were adopted to test the validity of the EKC hypothesis in the Nigerian economy. It was established that the EKC theory of inverted – U shaped relationship between economic growth (GDP) and carbon dioxide (CO₂) emission (through industrial development) is applicable in the Nigerian economy. This highlights the fact that high level of economic activities in pursuit of economic growth significantly increases CO₂ emission which in turn reduces environmental quality at the initial stage. But as the economy advances it becomes environmental friendly. Policy options to strengthen and maintain sustainable growth in Nigerian economy without neglecting or compromising environmental sustainability have been suggested.

KEYWORDS: Economic growth, Environmental quality, financial development, Environmental Kuznets Curve (EKC).

JEL CLASSIFICATION: Q01, Q56, Q54.

1.0 INTRODUCTION

Economic growth is a continuous process by which productive capacity of the economy is increased overtime, leading to rising levels of national output and income. It is made up of three components: capital accumulation, growth in population and technological progress. (Elias et 'al 2018). The process of growth or increase or advancement from any of these components is environmentally unfriendly; for this reason, the growth of the economy has been one of the high priority subjects for policy makers and economists usually since after world war II and particularly in the 1960's when environmental problems such as pollution and noise pollution were on the rise in conjunction with the growth of the economy. It was around this time (1960s), as the concern about environmental problem was on the increase that for the first time, the "club of Rome" in their report proposed ideas to limit growth. And today, there are also arguments that the nature has reached its limit to accommodate pollution and therefore there is the need to limit growth and consumption (Sarae & Yaglikara, 2017).

However, some critics argue that pollution was not caused by economic growth rather by a defect in the pricing system - meaning inability of policy makers to internalize the external effect in the pricing systems (Brunoll & medin, 2003). Other supporters of economic growth argue that if economic growth is decoupled from its impacts, such as energy and other materials through part and waste production, and there impacts reduced to harmless levels through improved efficiency, then economic growth would cease to be a problem for the environment. It is based on this rational that the ecomodernists believe that economic growth and environmental quality are compatible and not at odds with each other. Yet others maintain that the enormous increase in infrastructural projects and expansion of industrial sites and urban settlements has obviously changed the natural environment, (Xiaozi etal (2006), orr (2018), Vorma & Kamelpel (2011), Katsoubkos & Kotsius (2016), Datta & De (2021))

West Africa is an extremely large region of 21 diverse countries that inherited rich ecosystem. Among these ecosystems the Guinean forests are recognized among the 35 global biodiversity hotspots where diversity of plants and animals exist. However the ecosystems are recently facing great pressure from increasing population and human activities ranging from unsustainable

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and illegal land use practices, quest for growth and development through expansion in industrial production, technological advancement and trade liberalization etc. These activities create environmental issue and endanger human life by the emission of CO₂ which cause increase in atmosphere greenhouse gases (Karla, 2021) “Environmental issues are those harmful impacts or human activity on the environment. African environmental issues are influenced by anthropogenic effects on the African natural environment and have major impacts on the environment and nearly all kinds of endemic life. These issues involve for example: Deforestation, soil degradation, air pollution, water pollution, garbage pollution, climate change and scarcity” etc. <https://en.wikipedia.org/wiki/environmentalissuesinafrica..>

The protection of the national environment and restoration of West African wild life and forest are crucial to: sustaining the regions biological heritage for generation yet to come, achieving the global carbon emission reduction targets and lowering the increasing amount of greenhouse gases in the atmosphere to a manageable rate. Apart from the external affects of individual and collective activities Nigerian environment, it is also understandable that West Africa. Particularly Nigeria is vulnerable to major global energy and climate changes. This vulnerability is caused by such factors like: weak adaptive capacity, high dependence on Eco system advantages for livelihood, and less improved agriculture production system (Ofegbu & Chinwe, 2019). It is because of this vulnerability that some scholars are worried because major global energy and climate challenges rises the risk of geopolitical/geographical fractures and new international dividing lines mainly between developed economies and developing economies (Birol 2020).

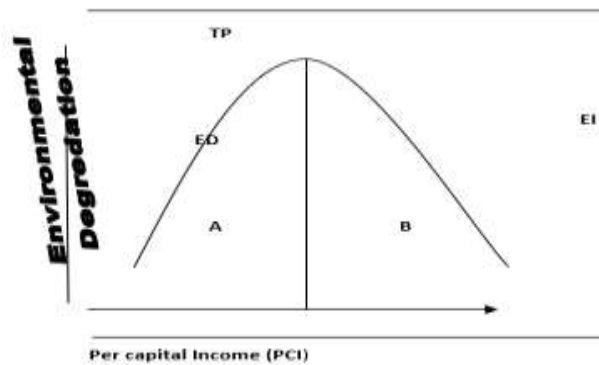
The rate at which population growth, expansion of infrastructures, increase in industrial sites and urban settlements effect the environment is becoming worrisome and therefore the relationship between economic growth and environmental quality is now a hot debatable topic. Many scholars have examined the “economic development – environmental” relationship. The environmental kuznets curve (EKC) is one prominent hypothesis that has attracted much attention on this relationship (Arrow et’al 1995). It (EKC hypothesis) was advocated in the 1990s by Grossman & Kruegar (1991) and Shafik & Bandyopadhyay, (1992). The EKC concept suggests that there is an inverted U- shaped relationship between economic growth and environmental pollution. It further states that the environment decrease in quality during early periods of economic growth, but rises when per capital income reaches a certain point - the turning point (Alam & Kebir 2013). This assertion may be interpreted thus; as economic growth (income level) exceeds the turning point, it leads to environmental improvement, meaning that environmental pollution per capital is an inverted U- shaped function of per capital income. Indeed whether this conclusion is common to all nations is a question yet to be answered.

However, many studies have investigated the EKC hypothesis either through the approach of theoretical or empirical evidence. For instance, Lee, 2005; song et’al, (2008); Andreoni & Levinse, (2000); stern, (2003); liu et’al, (2007); Binder & Neumayer, (2005); are some of the pioneer studies that have empirically proved the concept of EKC in some developed and developing nations. Most of the studies draw attention to a common point that environmental quality deteriorates at the beginning of economic growth but subsequently improves as the economy grows to a certain point where per capital income is high.

Also scholars like Xiaozi et’al, (2006) and David, (2018) adopted theoretical method to analyse the EKC hypothesis. They observed mixed results showing that production-induced pollutants support EKC hypothesis while consumption induced pollutants do not give support. There is also another mixed finding from Alam & Kabir, (2013) whose study reads that as GDP increases, per capital income seems to have positive impact on the pollution measure, but the results on eco-efficiency was a mix (both positive and negative) results. Therefore it failed to prove the EKE concept entirely.

From the views of these authors, the EKC shows the relationship that exists between indicators of environment pollution and economic growth or per capital income. It tries to prove that though environmental quality decreases during initial stages of economic growth; at high level of income, the high growth attended provides environmental improvement. Therefore the relationship between Environmental Quality and Gross Domestic Product (GDP) in an economy depicts an inverted U sharp as shown below.

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Source: Sarac & Yaglikara, (2017)

EI – Environmental improvement

TD – Turning point

ED – Environmental Degradation

Figure 1 is a typical EKC hypothesis which maintains that environmental pollution increase as economic growth increase at the initial stage but after a certain level of income, the growth of the economy allows environmental remediation (Beak, (2015); Yamidle, Bhattarai & Vijaraghovan, (2004)). This relationship is as a result of three factors: The scale effect, the composition effect and the technological effect. The sale effect shows that increase in production resulting from the use of more natural resources increase environmental damage. This is shown in part A of figure 1, where environmental pollution is a positive function of per capital income. The composition affect is due to a shift from the manufacturing industry to the service industry that brings a change in economic structure and consequently reduces environmental pollution through fewer uses of natural resources. The technological effect is as a result of increase in technological investment and also increase in research and development (due to a rise in national income) which allows the use of environmental-friendly technologies and reduces environmental pollution as show in part B of figure 1, where environmental pollution is a negative function of per capital income. (Eratas & Uysal 2014).

The aim of this study therefore is to investigate whether the assertion that at a certain stage of economic advancement, environmental pollution becomes a negative function of economic growth. In order words we seek to verify the validity of the EKC hypothesis in the Nigerian context. The null hypothesis guiding this study is: “there is no inverted – U shaped relationship between economic growth and carbon emission”,

2.0 LITERATURE REVIEW

2.1 Conceptual literature

The EKC hypothesis is a theory created on the basis of Kuznets hypothesis (1995) based on the inequality of income and economic development. It deals with the relationship between different indicators of environmental pollution and per capita income and maintains that environmental pollution increases as economic growth increases at the initial stage but after a certain level of income, the growth of the economy allows environmental remediation.

Economic growth is a sustained increase in the economic variables of an economy mainly the ‘GDP’ over a period of time and its main characteristics are high rates of growth per capita income or output, high rate of production, high rate of structural transformation etc (Nwaru & Okorontah, 2014).

Carbon dioxide (CO₂) emission is the main greenhouse gas that usually causes global warming. It is mostly related to energy from which the production and consumption of goods and services continue around the world. Therefore policies regarding emission and environmental issues are directly related to the relation between CO₂ and economic growth (Saatei & Dumrul, 2012).

2.2 Theoretical Literature

Environmental sustainability (ES) has recently entered the center stage of many economic policies. The linkage between ES, economic growth and some other economic and non economic variables has been treated in many studies. Two prominent theories in this area are the Environmental Kuznet Curve (EKC) theory and the Environmental Transition (ET) theory.

The EKC theory hypothesizes that economic growth and development reduces the quality of the environment initially but after some level of progress, the proceeds of economic growth aids in the reduction of environmental degradation. It is assumed that economic growth through production activities results in continuous environmental pollution that is detrimental to ES. Also there is rise in the demand for energy and increased use of natural resources and economies seek higher growth and development which obviously increases wastes and excess CO₂ emission (Iheoma et’al 2022, Nathaniel &Khan 2020)

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The ET theory argues that there are diverse environmental issues relating to growth and advancement that is not in line with the EKC hypothesis. Mcgranaham et al 2001 asserts that as nations grow wealthier, their environmental effects move from local menace to world ecosystem problems; and such ecological menace transforms from the rural level of poor sanitation and poor water accessibility to urban problems of air and water pollution because many rural areas become urban areas.

2.3 Empirical Literature.

Several works have been carried out both in Nigeria and outside Nigeria that examined the validity of the Kuznets curve hypothesis. Some of these studies are reviewed as presented on Table 1.

Table 1. Reviewed works:

Authors/Year	Topic and country of interest	Technique applied	Finding(s)/Result
Musibua et al (2021)	Environmental performance in the West African economy.	Two stage least square 2(SLS) and moment quartile methods	Discovered that environmental performance is positively related to economic growth.
Anochiwa et al (2022)	Assessing the distribution effects of financial development (FD) on consumption-based carbon emission in sub-Saharan Africa	A quartile – based analysis	FD significantly determines the region's ES through CDE.
Liu (2005)	Explaining the relationship between CO2 emission and national income: The role of energy consumption. NAFTA	Panel data estimation	EKC is valid in NAFTA Countries.
Apergis & Payne (2010)	The emissions, energy consumption and growth nexus: Evidence from the commonwealth of independent states.	A panel cointegration and error correction method.	EKC is valid.
Khan, Khan & Muhammad (2020)	The relationship between energy consumption, economic growth and carbon dioxide emission in Pakistan.	Dynamic panel model	FD significantly worsens the ES of selected nations, but energy utilization significantly increased CDE.
Omoko & Nwana (2020)	Does bank credit to the private sector promote low carbon development in Brazil	ARDL Simulations	FD has long-run inverse influence on ES.
Acaravai & Ozturk (2010)	On the relationship of energy consumption, CO2 emission and economic growth, (1960-2003) European Countries.	Panel cointegration ARDL.	EKC is not valid for most of the countries.
Mor and Jindal (2010)	Estimation of environmental Kuznets curve and Kyoto parties	A panel data Analysis	EKC is valid.
Ozturk & Ertugrul (2015)	Estimating Kuznet curve - in the mint countries (1967-2010)	Panel causality long-run analysis.	EKC is valid in the countries Turkey and Mexico.
Musah et al (2020)	Financial development and Environmental Sustainability in West Africa	Heterogeneous and cross sectional models	FD is detrimental to EQ in West Africa through increase in CDE.
Baek (2015)	Environmental Kuznet curve for CO2 emission: The case of African Countries (1960-2010)	Panel cointegration ARDL	EKC is valid in all the countries.
Boafeteh & Saadaui (2020)	Do asymmetric financial development shocks matter for CO2 emission in Africa? - 22 African countries	Non linear panel ARDL – PGM approach	FD has long-run term inverse influence on ES.

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Song, Zhang & Tong (2008)	An empirical test of the environmental Kuznets Curve in China.	Panel cointegration , and FMOLS estimation.	EKC is valid in China
Mesagan et al (2022)	Comparative analysis of the growth impact of pollution and energy in selected West African nations.	Granger causality and full maximum OLS estimation technique.	Increased energy consumption and carbon emission enhanced economic growth in West Africa.
Shahbaz et al (2014)	Environmental Kuznets curve in an open economy: A bounds test and causality analysis for Tunisia.	Vector error correction model (VECM) and causality estimation technique.	Findings support the EKC view. Strongly pointed tread openness as a co-driver of environmental quality.
Rafindadi (2016)	Does the need for economic growth influence energy consumption and Co2 emission in Nigeria?	Diverse dynamic estimation technique – ARDL, VECM, and causality approaches.	Financial development significantly increases energy utilization, while economic growth reduces energy utilization but worsens environmental quality in Nigeria
Mesagan & Olunkwa (2022)	Heterogeneous analysis of energy consumption, financial development, and pollution for 18 Africa countries,	ARDL-PMG and pooled mean group estimation methods.	Financial development has a long term inverse influence on environmental sustainability, but enhances environmental sustainability in the short run.
Khan et al (2021)	Impact of financial development and energy consumption and environmental degradation in 184 countries using a dynamic panel model.	Dynamic econometrics estimation techniques	Financial deepening significantly worsens the environmental quality of the selected nations, while energy utilization increases CDE
Boutafeh & Saadaoui (2020)	Do asymmetric financial development shocks matter for Co2 emission in Africa? – 22 African Countries.	ARDL – PMG and pooled mean group estimation methods.	Financial development had a long-term inverse relationship with environmental sustainability.
Osuntuyi & Lean (2022)	Economic growth, energy consumption and environmental degradation nexus in heterogeneous Countries. Does education matter – 92 countries?	ARDL – PMG and heterogeneous causality estimation method.	The consumption of energy has a negative effect on environmental pollution and environmental degradation.
Marques et al (2018)	The impact of economic growth on Co2 emission in Australia: The environmental Kuznets curve and the decoupling index.	Dynamic ordinary least square (OLS) and an autoregressive distributed lag model.	Economic growth has a significant negative long-run effect on Co2 – using Australian data.
Kahan et al (2022)	Environmental consequences of financial development in emerging and growth – leading economies: multidimensional assessment	Panel data analysis	Financial development strike a win – win balance between economic growth and environmental sustainability.
Asongu et al (2019)	The criticality of growth, urbanization, electricity and fossil fuel consumption to environmental sustainability in Africa.	Pooled mean group (PMG) version of ARDL technique	Result confirmed that the environmental Kuznets curve postulation is possible.

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From Table 1 above, it is observed that, there are different results. Many are in agreement with the Kuznets hypothesis while some others differed and showed N shaped relation. (ie the pollution starts to increase again at higher level of income. This study differed from all the studies reviewed in one aspect or the other. In time period it differed from all of them because it extends to the nearest present year -2023 considering the availability of data. Consequently the study is specific by studying Nigeria unlike other studies that included many countries and generalized there results on those countries. In methodology it differed from existing works particularly on Nigeria by adopting multivariate framework using the VECM to determine the relationship between the explanatory variables and environmental sustainability, but is similar to the work of Sarac and Yaglikara (2017) who adopted panel regression model for Black Sea Economic Cooperation Countries from 1992-2011 to investigate the relationship between economic growth, energy consumption and CO₂ emission. However, it departs from Sarac and Yaglikara work by adopting VECM and conducted causality test in addition.

3.0 METHODOLOGY AND MODEL SPECIFICATION.

This study gathered time series data covering the period 1991 – 2023. Based on the study’s objective of assessing the validity of the environmental Kuznets curve hypothesis the following variables were considered: economic growth, financial development and carbon dioxide (CO₂) emission. The time series data were extracted from Central Bank of Nigeria statistical bulletin and World Bank data repository. The study relies on various methodologies for its estimation and relevant policy statements. Further to the typical descriptive statistics, the designated time series data were estimated using the unit root test (which indicates the stationarity level of the concerned variables), co integration and vector-autoregressive model as drawn from the result of the unit root.

Table 1 below is presented for in depth exposition of the composition of the variables.

Table 1: Data Description

Variables	Notations	Unit of measurement	Source
Carbon dioxide (CO ₂) emission	COE	Metric tons per capita	WDI
Gross domestic product	GDP & GDP ²	At current market price (Naira)	CBN
Financial development	FDM	Domestic credit to private sector (%GDP)	WDI/CBN

Note: WDI denotes World Development Indicator (World Bank’s data repository). CBN denotes Central Bank of Nigeria.

Considering the Environmental Kuznets Curve Hypothesis (EKC) and in line with some relevant prior studies, (Sarac &Yaglikara, 2017; Ozturk &Ertugrul, 2015), this study applied quarterly time series data and used Vector Autoregressive (VAR) model to evaluate the relationship between GDP, GDP², FDM, and COE. The reason for including the variable (FDM) is rooted on its critical role in effecting Environmental sustainability (ES) which is consistent with the relevant prior studies. Therefore the EKC function of the regression model form for this study is:

$$COE = f(GDP, GDP^2, FDM) \dots \dots \dots (1)$$

The model in its Vector Autoregressive (VAR) general form is:

$$Y_{it} = \alpha_i + \beta_i \sum_{k=1}^n y_{it-1} + \delta_i \sum_{k=1}^n x_{it-1} + v_j \dots \dots \dots (2)$$

Y_{it} = 4 x 1 vector of endogenous variables (ie y_{it} = COE_t, GDP_t, GDP²_t and FDM_t)

α_i = 4 x1 vector of constant term

β_i = 4 x 4 coefficient matrix of the autoregressive term

δ_i = 4 x4 coefficient matrix of the explanatory variables (vector of coefficient)

V_i = vector of innovation.

Equatin (2) can be re-written thus:

$$COE_t = \alpha_0 + \alpha_1 \sum_{k=1}^n COE_{t-1} + \alpha_2 \sum_{k=1}^n GDP_{t-1} + \alpha_3 \sum_{k=1}^n GDP_{t-1}^2 + \alpha_4 \sum_{k=1}^n FDM_{t-1} + U_{1t} \dots \dots \dots (3)$$

$$GDP_t = \beta_0 + \alpha_1 \sum_{k=1}^n GDP_{t-1} + \alpha_2 \sum_{k=1}^n COE_{t-1} + \alpha_3 \sum_{k=1}^n GDP_{t-1}^2 + \alpha_4 \sum_{k=1}^n FDM_{t-1} + U_{2t} \dots \dots \dots (4)$$

$$GDP_t^2 = \pi_0 + \alpha_1 \sum_{k=1}^n GDP_{t-1}^2 + \alpha_2 \sum_{k=1}^n COE_{t-1} + \alpha_3 \sum_{k=1}^n GDP_{t-1} + \alpha_4 \sum_{k=1}^n FDM_{t-1} + U_{3t} \dots \dots \dots (5)$$

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$$FDM_t = \phi_0 + \alpha_1 \sum_{k=1}^n FDM_{t-k} + \alpha_2 \sum_{k=1}^n COE_{t-k} + \alpha_3 \sum_{k=1}^n GDP_{t-k} + \alpha_4 \sum_{k=1}^n GDP_{t-k}^2 + U_{4t} \quad (6)$$

Where k is the lag length, n is the maximum distributed lag length, $\alpha_0, \beta_0, \pi_0, \phi_0$ are the constant terms, U_t is the identically and independently distributed (iid) stochastic error term, and t is subscript depicting time or period. It is expected that α_2 and α_3 values should be positive and negative respectively according to the EKC approach. This means that the COE rises with increasing level of income up to a level of turning point and then decreases. Also the value of β_3 is expected to be positive.

In matrix form, the above can be compactly specified as in equation 7

$$\begin{bmatrix} COE_t \\ GDP_t \\ GDP_t^2 \\ FDM_t \end{bmatrix} = \begin{bmatrix} \alpha_0 \\ \beta_0 \\ \pi_0 \\ \phi_0 \end{bmatrix} + \sum_{k=1}^n \begin{bmatrix} COE_{t-k} & GDP_{t-k} & GDP_{t-k}^2 & FDM_{t-k} \\ GDP_{t-k} & COE_{t-k} & GDP_{t-k} & FDM_{t-k} \\ GDP_{t-k}^2 & COE_{t-k} & GDP_{t-k} & FDM_{t-k} \\ FDM_{t-k} & GDP_{t-k} & COE_{t-k} & GDP_{t-k}^2 \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \quad (7)$$

Transforming the VAR equation into VECM specifications corresponding to:

$$\Delta COE_t = \alpha_0 + \alpha_1 \sum_{k=1}^n \Delta COE_{t-k} + \alpha_2 \sum_{k=1}^n \Delta GDP_{t-k} + \alpha_3 \sum_{k=1}^n \Delta GDP_{t-k}^2 + \alpha_4 \sum_{k=1}^n \Delta FDM_{t-k} + \varepsilon_{1t} \quad (8)$$

$$\Delta GDP_t = \beta_0 + \alpha_1 \sum_{k=1}^n \Delta GDP_{t-k} + \alpha_2 \sum_{k=1}^n \Delta COE_{t-k} + \alpha_3 \sum_{k=1}^n \Delta GDP_{t-k}^2 + \alpha_4 \sum_{k=1}^n \Delta FDM_{t-k} + \varepsilon_{2t} \quad (9)$$

$$\Delta GDP_t^2 = \pi_0 + \alpha_1 \sum_{k=1}^n \Delta GDP_{t-k}^2 + \alpha_2 \sum_{k=1}^n \Delta COE_{t-k} + \alpha_3 \sum_{k=1}^n \Delta GDP_{t-k} + \alpha_4 \sum_{k=1}^n \Delta FDM_{t-k} + \varepsilon_{3t} \quad (10)$$

$$\Delta FDM_t = \phi_0 + \alpha_1 \sum_{k=1}^n \Delta FDM_{t-k} + \alpha_2 \sum_{k=1}^n \Delta COE_{t-k} + \alpha_3 \sum_{k=1}^n \Delta GDP_{t-k} + \alpha_4 \sum_{k=1}^n \Delta GDP_{t-k}^2 + \varepsilon_{4t} \quad (11)$$

The decision to use VAR model which is transformed into a vector error correction mechanism (VECM) is made because it is among the models that is not vulnerable to simultaneity bias. It makes the explanation, prediction and forecasting of the values of a set of economic variables simple at any point in time. It has the capability of testing for weak exogeneity and parameter restrictions. One of its assumptions is that there is no priory direction of causality among variables. A good characteristic of the VAR model is that it precludes a decision as to what contemporaneous variables are exogenous with only lagged variables on the right-hand, and all variables are endogenous.

4.0 EMPIRICAL RESULTS AND DISCUSSION

As noted previously that steps were thought relevant for the ultimate robust inferences and policy recommendation that emerge from analyses. For this reason, the descriptive statistics on table 2 is the first result of the empirical steps discussed in this section.

Table 2. Descriptive statistics

	COE	GDP	GDP2	FDM
Mean	10.63353	12.06752	24.13504	2.310774
Median	10.52500	12.53631	25.07263	2.322388
Maximum	11.17115	13.26070	26.52141	2.955530
Minimum	10.01032	10.23107	20.46214	1.648659
Std.Dev.	0.392089	1.008939	2.017878	0.315529
Skewness	0.063516	-0.387940	-0.387940	0.064068
Kurtosis	2.816252	5.516628	5.516628	3.114714
Jarque – Bera	3.471844	3.853274	3.853274	0.493595
Probability	0.176308	0.145637	0.145637	0.781299

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Sum	350.9065	3982282	796.4564	76.25555
Sum sq. Dev.	4.927020	32.57464	130.2986	3.185872
Observations	132	132	132	132

Source: Authors' Computation (2024)

The descriptive statistics of the dataset is presented on table 2 to verify the normality of the dataset for further econometric analysis. From the observed figures, the data are normally distributed because the mean and the median values of the included variables are almost the same. According to Karmu and Polasek (1980), dataset is normally distributed or symmetrical when the mean, mode and median values are identical. Also useful information which attests to the normal distribution of the dataset is seen in the maximum and minimum values. Furthermore that the sample set is normally distributed is proved through the values of Skewness, Kurtosis and Jaque-Bara statistics. Skewness statistics demonstrated that some series skewed to the right and some to the left, depicting the symmetric nature of the dataset. Kurtosis statistics measures the peaked natures or flatness of the distribution of the series; it reveals that COE and FDM are normally distributed while GDP and GDP2 are leptokurtic since their distributions are peaked (approximately greater than 3). As well the Jaque-Bara statistics are not significant supporting the normal distribution of the data series. Remarkably the series normal distribution is a good reason for adopting the VAR model.

Unit Root Test

In considering the unit root test, Nelson & Ploser (1982) maintained that, a common consideration is whether the data should be differenced before application or applied in terms of level. Generally, if the variables in the model are non-stationary, then the data should be differenced to avoid spurious result. The Augmented Dicky fuller (ADF) unit root test constructed by Engel & Granger (1987) is used in this study.

Table 3. ADF unit root result

Variable	ADF statistics			
	Level	First difference	critical value 5%	1(d)
COE	-0.330988	-6.140016	-2.957110	1(1)
GDP	-0.908231	-4.439349	-2.957110	1(1)
GDP ²	-0.908231	4.439348	-2.957110	1(1)
FDM	-2.131986	-5.457400	-2.957110	1(1)

Note: significant level is at 5% (critical value).

From the result of the unit root test all the variables are stationary at the first difference. This result further informs co integration and possible Vector-autoregressive (VAR) model estimation to establish relationship.

Johansen Co integration Test

The next step is to test whether these time series data can be used together to give meaningful result in the long-run and this is derived through the co integration test. This study adopted the Johansen co integration test which was developed by Johansen (1995). The choice of this approach is because it adopts the Full Information Maximum Likelihood (FIML). It is based on the VAR model given as folloes:

$$Y_t = A_1 Y_{t-1} + A_p Y_{t-p} + \beta_{xt} - e_t$$

(3) where: Y_t is K vector of non stationary 1(1) variable, A_t is the d- vector of determinant variable and e_t is a vector of innovation. $A_1 - A_p$ and β are parameter estimates. If the variables are co integrated, then arises the need for the test of error correction model.

Table 4 Co integration Test

Hypnotized No of CE(s)	Eigenvalue	Trace	Statistic	0.05 Critical value	Prob*
None*	0.701950	86.05269		47.85613	0.0000
At most 1*	0.619670	48.52733		29.79707	0.0001
At most 2*	0.424226	18.55016		15.49471	0.0167
At most 3	0.045572	1.445943		3.841466	0.2292

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Trace test indicates 3 co integrating equations at the 0.05 level

*denotes rejection of the hypotheses at the 0.05 level

**Mackinnon-Haug-Michelis (1999) P.value.

The co integration result indicates that, there is at least three co integrating equations, hence the rejection of 'At mosi 2*' hypothesis. This suggests the existence of a long-run equilibrium relationship between the explanatory variables and the dependent variable.

Vector Error Correction Model (VECM) Results (Tables 5a -5c)

Table 5a. Variables included in the VECM – COE and GDP, GDP², FDM

Variables	a's	ECM
COE	1.0000	-0.062419 (-0.04661)
GDP	0.290985 (0.04356)	-0.509505 (0.24827)
GDP ²	-3.17E-07 (7.3E-08)	-2.910590 (-1.40675)
FDM	4051.405 (615.901)	-4.74E-05 (1.1E-05)
C = -44204.23		

Table 5b. Variables included in the VECM: GDP and COE, GDP², FDM

Variables	a's	ECM
GDP	1.0000	0.148259 (-0.07224)
COE	-3.436607 (0.58372)	0.018163 (-0.1356)
GDP ²	-1.09E-06 (1.1E-07)	84693.76 (60205.1)
FDM	-13923.09 (1688.14)	1.38E-05 (3.3E-06)
C = 15192.6		

Table 5c. Variables included in the VECM; FDM and COE, GDP, GDP²

Variables	a's	ECM
FDM	1.0000	-0.192193 (-4.323405)
GDP	-7.18E-05 (8.3E-06)	-2064.716 (-2.05225)
COE	0.000247 (4.0E-05)	-1.18E+09 (-1.40615)
GDP ²	7.82E-11 (1.6E-11)	-252.8834 (-1.33905)
C = -10.91084		

Table 5d. Variables included in the VECM: GDP² and COE, GDP, FDM

Variables	a's	ECM
GDP ²	1.000000	-0.092218 (0.06555)
COE	315619.8	-198E-08

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	(60869.1)	(1.5E-08)
GDP	-918405.2 (69158.1)	-1.61E-07 (7.9E-08)
FDM	1.28E+10 (2.0E+09)	-1.50E-11 (3.5E-12)
C = -1.04E+11		

The normalized long-run co integrating equation of the variables from the estimated model (5a – 5d) could be written as:

$$COE = -44204.23 + 0.290985GDP - 3.17E-07GDP^2 + 4051.405FDM.$$

$$GDP = 151912.6 - 3.436607COE - 1.09E-06GDP^2 - 13923.09FDM$$

$$FDM = -10.91084 - 7.18E-05GDP + 0.000247COE + 7.82E-11GDP^2$$

$$GDP^2 = -1.04E+11 + 315619.8COE - 918405.2GDP = 1.28E+10FDM$$

The purpose of the above estimations relied on explaining the heterogeneous influence of economic growth and financial development on environmental sustainability in Nigeria. Based on the result of Table 5a, it is important to emphasise that among other interesting results; economic growth variables (GDP and GDP²) depict that at early stage of development, as the economy grows (that is increase in GDP), it positively impacts or leads to increase in CO₂ emission which results to environmental quality degradation. However the negative impact of square of Gross Domestic Product (GDP²) on Carbon dioxide (CO₂) emission suggests that as economic growth continues progressively, a time comes when the relationship between society and its environments is enhanced resulting to reduction of environmental degradation. This result supports the Kuznets U-Shap hypothesis and is in agreement with those of Sarac and yaglikara (2017), Shahbaz et al (2014, Osuntuyi and Lean (2022), Khan et al (2021), Rafidadi (2016) and Odionye at al 2024. Considering Financial Development (FDM), it is clearly shown that its impact increases carbon emission in Nigeria. This demonstrates that the influence of FDM on environmental sustainability through CO₂ emission increases heterogeneously as FDM deepens. The implication is that Financial Development worsens the national environmental sustainability because as the national's financial sector grows and increases in magnitude it increases CO₂ emission which results to enervation of the environmental quality of the country. This outcome agrees with the works of Ye et al (2020), Ahmed et al (2021), and Mutal et al (2022) but contradicts the finding of Mesagan and Olunkwu (2022).

The vector error correction term for COE is -0.062. This speed of adjustment suggests that about 62 percent of the previous disequilibrium in the model is corrected quarterly. Also the error correction term for GDP, GDP² and FDM are -0.509805, -0.910592 and -0.74E-05 respectively. This results depicts a high speed of adjustment for any disequilibrium in the model.

Table 6 - Pairwise Granger Causality Test

Null hypothesis (H ₀)	Obs	F-statistics	prob	Decision
GDP does not granger cause COE	130	4.55595	0.0201	Reject H ₀
COE does not granger cause GDP	130	0.06719	0.9352	Do not reject H ₀
GDP ² does not granger cause COE	130	2.26040	0.1244	Do not reject H ₀
COE does not granger cause GDP ²	130	2.02819	0.1519	Do not reject H ₀
FDM does not granger cause COE	130	12.3780	0.0002	Reject H ₀
COE does not granger cause FDM	130	1.59600	0.2219	Do not reject H ₀

The pairwise granger causality test is presented on table 6. The result depicts that there are different direction of causality between Co₂ and the explanatory variables. It was observed that GDP and FDM granger cause Co₂ without a feedback. This showed a strong unidirectional causality running from GDP and FDM to Co₂. The result also revealed that there was independent causality between GDP² and Co₂, this means that GDP² does not granger cause Co₂ neither does Co₂ granger cause GDP². These conclusions follow the values of the f – statistic which is statistically significant at 5 percent level of significance for GDP and FDM but insignificant at the same level of significance for GDP² as indicated by their P-values. This result is robust and satisfied the theory and implication of the EKC theory that at early stage of economic growth and development pollution and other environmental hazards increase faster, but after some level of economic advancement environmental pollution decreases through the utilization of clean technology and transition to service based economic activities.

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SUMMARY AND POLICY RECOMMENDATION

This study investigated the validity of the environmental Kuznet curve (EKC) hypothesis in the Nigerian context. Considering the nature of the variables and the objectives of the study, the vector autoregressive (VAR) model transformed into a vector error correction model (VECM) was adopted. The EKC hypothesis presumed that there is a relationship between environmental pollution and economic activities (mainly economic growth), and this relation is interpreted thus: At early stage of the economies progress, the carbon emission (Co₂) increases, but after a certain level of increase in economic growth the Co₂ decreases gradually as the economy continues in progress, depicting that the EKC function takes the form of reverse – U shape.

From empirical EKC literature, some studies like Musal et al (2022), Ahmed et al (2021), Apergis & Payre (2010) & Mor and Jindel (2022) establish that there is an inverted – U shaped relationship between income (GDP) and Co₂. The analysis of our data gave support to these studies..

The summary of the findings of this study are as stated below:

- ◆ the variables have no unit root. This assertion is from the ADF test which indicated that the series are integrated of order one 1(1).
- ◆ the Johansen co-integration test reveals three co-integrating vector between Co₂ and the explanatory variables. The implication is that, there is a stable long-run equilibrium relationship between environmental pollution and economic growth.
- ◆ the descriptive statistics test depicts that the data set is normally distributed and symmetrical. This is shown in the values of minimum and maximum column of the descriptive statistic table, and how the sample is distributed measured through the values of Skewness, Kurtosis and Jaque-Bara statistics.
- ◆ the analyzed co-integrated vector within the VECM framework shows that economic growth at early stage exert a positive and significant impact on carbon emission but at a later stage turned to exert a negative impact on the same carbon emission.
- ◆ financial development exerted a positive and significant impact on carbon emission.
- ◆ the result also revealed that the speed of adjustment is higher, when considering economic growth and carbon emission than when considering financial development and carbon emission.
- ◆ also from the granger causality test within the VECM framework, it was revealed that there is a unidirectional causality running from economic growth to environmental pollution.

POLICY RECOMMENDATION

From the outcome of the results, there is a long-run relationship between environmental pollution and the included variables. Economic growth impacted positively and negatively on the environment depending on time/horizon and the stage of the economy. The study recommended thus

- There is need for the government of Nigeria to adopt income rising policies and implement them properly.
- Reduce pollution to a bearable minimum. To achieve this, companies and public enterprises in Nigeria are advised to use clean technology and the government needs to adopt a formidable legal regulation to stop gas flaring and other anti social activities.
- Also the development policies to be carried out in Nigeria have to be based on sustainable growth targets geared towards achieving the United Nations Sustainable Development Goals (SDGs).
- Lastly, it is necessary to consider technology, financial development and the environment together with lawful regulations so as to select environmentally friendly projects that will benefit the people through less pollution and improvement in the standard of living in urban areas.

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