Research Article

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Nigeria: Is There an Environmental Kuznets Curve for Fluorinated Gases?

https://doi.org/10.1515/openec-2020-0113
received June 9, 2019; accepted June 18, 2021.

Abstract: The environmental Kuznets curve is a relationship between various indicators of environmental degradation and income per capita. Empirical studies have produced mixed results concerning Environmental Kuznets Curve hypothesis given the different indicators of environmental degradation used. But there has not been any validation of Environmental Kuznets Curve for powerful greenhouse gases like fluorinated gases that have a global warming effect up to 23 000 times greater than carbon dioxide (CO_2), and their emissions are rising strongly. This paper aimed to test the applicability of the Environmental Kuznets Curve in Nigeria from 1970-2018 by deploying the Auto Regressive Distributed Lag methodology, the bounds test shows that there's a long-run equilibrium relationship between Gross Domestic Product per capita, square of Gross Domestic Product per capita, alternative and nuclear energy, combustible renewable and waste, and adjusted savings: net forest depletion. Nonetheless, the results do not support the Environmental Kuznets Curve hypothesis both in the short-run and long-run and inverted U-shaped relationship was not found between fluorinated greenhouse gas emissions and growth in Nigeria. However, adopting fluorinated gas recycling and destruction processes, optimizing production to minimize emissions, and replacing these gases with alternatives are suggested for industrial users.

Keywords: Environmental Kuznets Curve; Greenhouse Gases; Environmental Degradation; Economic Growth; Auto Regressive Distributed Lag.

1 Introduction

Human activities—especially fossil-fuel combustion since the Industrial Revolution—are accountable for steady rises in atmospheric concentrations of numerous greenhouse gases, particularly carbon dioxide, organic chemicals called chlorofluorocarbons (CFCs), methane, nitrous oxide, ozone, and many others (Mann, 2019). Carbon dioxide, although not the most powerful of the greenhouse gases, is the most essential because of the enormous volumes discharged into the air by combustion of fossil fuels (e.g., gasoline, oil, coal) (Britannica, 2019). Greenhouse gases contribute to climate change and climate change has a sequentially accelerating impact on environmental degradation. However, the Environmental Kuznets Curve (EKC) presupposes that environmental degradation rises up to a certain level of income; after this level, it declines. In a nutshell, the Environmental Kuznets Curve portrays an inverted-U relationship between a certain pollution indicator and GDP per capita. The notion is that at low levels of income, pollution will be expanding, while at high levels of income pollution will be diminishing. A turning point will be attained, after which pollution is lessening. Invariably, the EKC is actually a long-term phenomenon since the economy needs time to attain the turning point of the EKC.

Grossman and Krueger (1991) first presented the Environmental Kuznets Curve (EKC) hypothesis for various environmental indicators such as CO_2 emissions. It was well accepted, particularly by international organizations in charge of public policy. Stern (2000), though, of the opinion that EKC is mainly an empirical phenomenon supported by not very good econometrics: “The EKC proposition rose to spotlight because few paid ample concentration to

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econometric diagnostic statistics. Little or no consideration has been given to the statistical properties of the data utilized, such as serial dependence or stochastic trends in time series and few tests of model suitability have been performed or ascertained. However, one of the principal reasons for performing econometrics is to evaluate which assumed relationships, or "stylized facts", are accurate and which are false correlations." According to Kalchev (2016) studies have been done with panel and time-series data. The panel studies may not be very useful in the sense that there is no global EKC valid for all countries. In fact, evidence suggests that the turning point is different for various countries (Kalchev, 2016). Single country studies have been engaging unit root and cointegration testing to reveal the correct relationship between pollution and income series and to avert spurious regressions. Jalil et al. (2010) recommend that a time-series study for a single country might offer superior framework to examine the relationship.

It is worth of noting here that various studies have examined the EKC hypothesis for different measures of environmental degradation, such as deforestation, carbon emissions and municipal waste (Cropper and Griffiths, 1994; List and Gallet, 1999; Lee et al., 2009; Ozturk and Acaravci, 2010; Oyebanji et al., 2017). However, sulphur dioxide and CO_2 have been amongst the most predominantly applied environmental degradation measures. But the role of fluorinated gases emission has been absolutely overlooked while discussing the environmental degradation and economic growth nexus. Yet, fluorinated greenhouse gases have a global warming effect up to 23 000 times greater than carbon dioxide (CO_2), and their emissions are rising strongly (Europa, 2020). Because of the global warming effect of fluorinated gases, the actions for managing it, especially those of hydro-fluorocarbon type (H-FC), are highly regulated. Due to the Montreal Protocol and its amendments, hydro-fluorocarbons have been prohibited from commercialization worldwide since 2015 (GreenFacts, 2019). The 2016 Kigali Amendment to the Montreal Protocol stipulates that from 2019, the industrialized countries commit to reducing the use of hydrofluorocarbons by 45% by 2024 and by 85% by 2036, compared to 2011-2013 levels (GreenFacts, 2019). Developing countries will begin to cap and reduce their consumption of hydrofluorocarbons starting in 2024 (GreenFacts, 2019).

Nevertheless, empirical studies have produced mixed results concerning EKC hypothesis given the different indicators of environmental degradation used (Shafik, 1994; Koop and Tole, 1999; Bhattarai and Hammig, 2001; Culas, 2007). But there has not been any validation of EKC for powerful greenhouse gases like fluorinated gases. Nonetheless, Carson (2010) shows that the validation of an EKC depends on econometric techniques, the quality of the data and the incorporation of other variables (Stern, 2003; Dinda, 2004).

Against this backdrop, using the most recent data sets available on Nigeria's emissions for airborne pollutants such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and Sulphur hexafluoride (SF6), which are fluorinated greenhouse gases, this paper aims to test the applicability of the EKC in Nigeria as a contribution to the theoretical debate. To the best of my knowledge, this paper is the first to test ECK using fluorinated greenhouse gases in Nigeria. Nigeria was chosen as a case study because both within-country and cross-country studies in the literature focused more on developed countries' cases. However, the structure of Nigeria's economy is typical of an underdeveloped country and dominated by pollution-intensive sectors. In this paper, the economic growth and environmental degradation are analyzed simultaneously in a single multivariate model using the Auto Regressive Distributed Lags (ARDL) approach to cointegration because when compared to other multivariate cointegration methods (i.e., Johansen and Juselius (1990)), the bounds test is a simple technique that allows the cointegration relationship to be estimated by OLS once the lag order of the model is identified. Secondly, its ability to host sufficient lags enables best capturing of the data generating process mechanism. This means that the method can be applied in determining the long-run relationship between time series irrespective of whether the time series is I(0), namely stationary at levels, I(1) namely stationary at first differences or fractionally integrated.

The rest of the paper is organized as follows: In section 2, an overview of Nigeria and fluorinated gases emission is presented. In section 3, a literature review was carried out. Section 4 is the methodological section. It covered issues concerning model specification and estimation technique. In section 5, a discussion of estimated regression results is hosted. Summary, conclusion and policy recommendations are available in section 6.

2 Nigeria and Fluorinated Greenhouse Gases Emission: Overview

Nigeria has the biggest economy and population of any country in Africa. It is anticipated to outdo China to turn into the world's second most populous country after India by the end of the century (Dunne, 2020). It was the world's 17th largest emitter of greenhouse gases in 2015, the second highest in Africa after South Africa (Dunne, 2020). The country's yearly greenhouse gas emissions were 506m tonnes of CO_2 equivalent ($MtCO_2e$) in 2015, according to data compiled by the Potsdam Institute for Climate Impact Research (PIK) (Dunne, 2020). The figure involves emissions from land use, land-use change and forestry (LULUCF). This is approximately the same as the United Kingdom's entire 2015 emissions (Dunne, 2020). Its per capita emissions in 2015 were about 2.8 tonnes of CO2e, far below the global average of 7 tonnes but around equal to the 2015 per-capita emissions of India (2.7 tonnes) (Dunne, 2020).

The country's economy is firmly bound to oil and gas exports. Profits from petroleum exports presently constitute 86% of Nigeria's total export revenue (Dunne, 2020). The production of oil and gas in Nigeria has also been linked to steep societal inequalities and environmental disasters. The Nigerian manufacturing sector is among the biggest in Africa. With a contribution of eight to nine percent, the sector contributes over $30 billion to the Gross Domestic Product (GDP) (Faminu, 2020).

Fluorinated gases are man-made gases emitted from a variety of manufacturing and industrial processes (Denchak, 2019). There are three main types of F-gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6) (NetRegs, 2020). As at 2012, the value for fluorinated greenhouse gases (F-gases) emissions which are by-product emissions of hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (thousand metric tons of CO_2 equivalent) in Nigeria was 76,219 (Index Mundi, 2019). Fluorinated greenhouse gases (F-gases) are a family of gases containing fluorine. Although fluorinated gases are emitted in smaller quantities than other greenhouse gases (they account for just 2 percent of man-made global greenhouse gas emissions) (Denchak, 2019), they are powerful greenhouse gases that trap heat in the atmosphere and contribute to global warming. They are stronger than naturally occurring greenhouse gases (Europa, 2020).

According to Europa (2020), fluorinated greenhouse gases are often used as substitutes for ozone-depleting substances, because they do not damage the atmospheric ozone layer. However, fluorinated greenhouse gases are powerful greenhouse gases, with a global warming effect up to 23 000 times greater than carbon dioxide (CO_2), and their emissions are rising strongly (Europa, 2020). From 1970-2012, fluorinated greenhouse gases emission (thousand metric tons of CO_2 equivalent) reached a maximum value of 174,955 in 2005 and a minimum value of 5,572 in 1974 in Nigeria (Index Mundi, 2019).

On the other hand, the value for GDP per capita (current LCU) in Nigeria was 551,511.40 as of 2016. As Figure 1 shows, over the past 56 years this indicator reached a maximum value of 551,511.40 in 2016 and a minimum value of 66.40 in 1960.

3 Literature Review

The affinity between development and inequality has been acknowledged for no less than 60 years (Beyene and Kotosz, 2020). Simon Kuznets investigated this linkage and brought about the Kuznets economic hypothesis. Kuznets (1955) stated that, at the earliest stage of economic growth, income inequality grows until it attains an utmost point, and then income inequality diminshines with economic development. Using the idea of the EKC hypothesis, Grossman and Krueger (1991) and Grossman and Krueger (1994) confirmed the relationship between per capita income and environmental degradation as having an inverted U-shape (see Figure 2).

Figure 2 depicts the inverse U-shaped graphical portrayal of the hypothesis. The dependent variable is environmental degradation, which is proxied by any pollutants (air, water and land or soil pollution) or deforestation. The dependent variable is per capita income.

In 1993, Panayotou pointed out that EKC is an imminent consequence of structural change accompanying economic growth. Afterward, Panayotou (2000) revealed that pollution emissions increase during country's industrialization and decline in the postindustrial stage. Cole (2000) finds that EKC could be the outcome of a dropping portion of

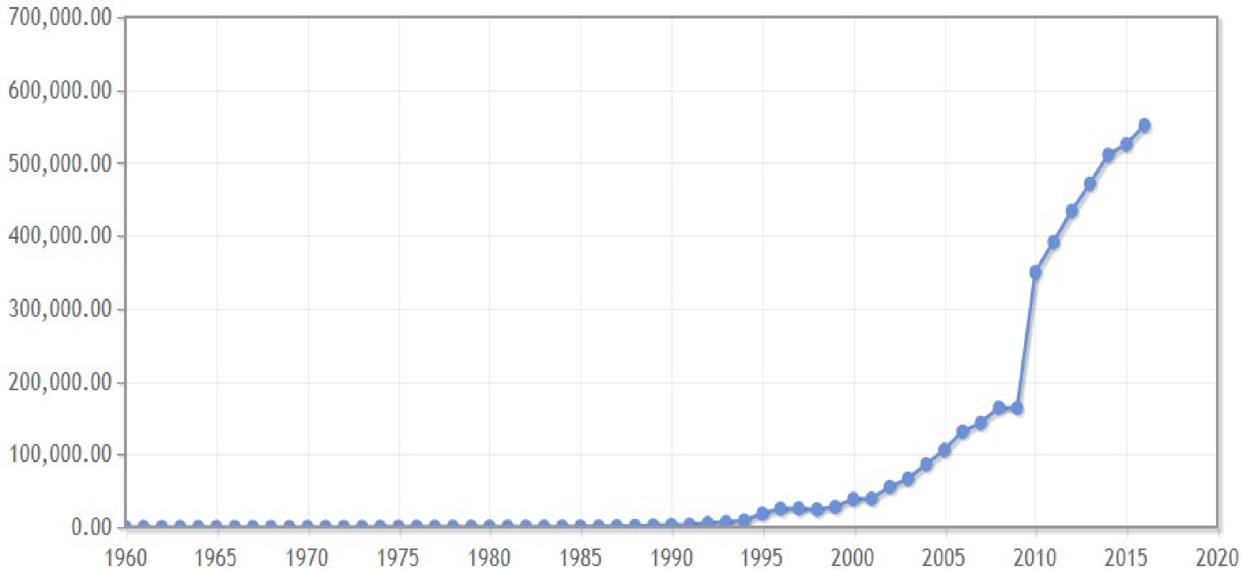

Figure 1: Nigeria - GDP per capita (current LCU). Source: Index Mundi (2018).

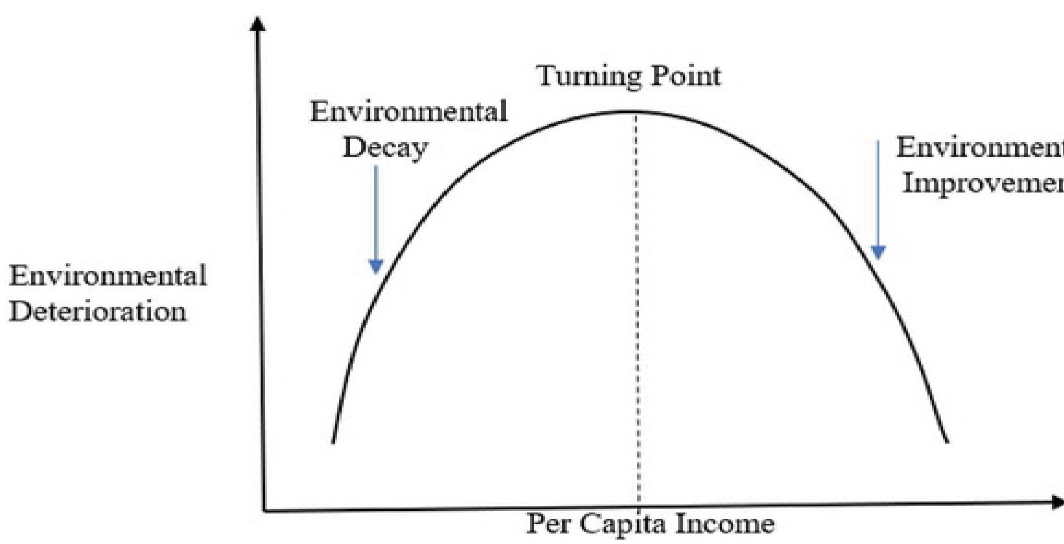

Figure 2: A typical EKC diagram. Source: Beyene and Kotosz (2020).

manufacturing and the drifting of the manufacturing to "clean" sectors away from "dirty" sectors. But he also points out that declining income elasticity of demand for pollution intensive products is connected with growing income level.

A large number of researchers have since carried out empirical tests between various indicators of environmental degradation and income per capita. In many cases, the level of environmental degradation, often a type of pollutant, measured in emissions per capita is assumed to be adequately described by a quadratic or a cubic polynomial function of per-capita income. This functional form is empirically tested for whether there would be a decline in environmental degradation for income levels higher than a particular threshold. Indeed, Bimonte (2002) and Grossman and Krueger (1995) observed an EKC for air pollutants such as sulphur dioxide, carbon monoxide or nitrogen oxides. Selden and Song (1994) explored the relation between air pollution and economic growth for four airborne emissions, Sulphur dioxide (SO_2), Nitrogen oxide (NO_2), suspended particulate matter (SPM) and Carbon monoxide (CO). Both time-series and cross-sectional data were collected from the World Resources (WRI, 1991).

Diminishing levels of emissions at high-income levels was discovered for all tested emissions except CO. The research depicts an outcome similar to the EKC where a sufficiently high-income level could lessen emission levels for some pollutants (SO_2, NO_2 and SPM), however, the authors state that the turning point where the emissions start to diminish is higher than originally thought. Given the current per capita GDP levels of the low-income economies of the world, there is a long way to go before global emission levels start to diminish. The hypothesis is rebuffed by Holtz-Eakin and Selden (1995) for carbon dioxide emissions. Vincent et al. (1997) find that SPM and chemical oxygen demand (COD) are increasing with income, while biochemical oxygen demand (BOD) is decreasing with income in Malaysia. Diputra and Baek (2018) explored growth-environment nexus in Indonesia and found little evidence that urbanization causes significant environmental degradation

Roca et al. (2001) analyzed the validity of the EKC hypothesis for Spain for six atmospheric pollutants. Time series data for carbon dioxide covered the period from 1972 to 1996, while data on other five pollutants covered the period from 1980 to 1996. The OLS model is a cubic specification that confirmed the hypothesis only in the case of sulphur dioxide and not for other pollutants. Friedl and Gelzner (2003) explored the relationship between economic development and carbon dioxide in Austria for the period from 1960 to 1999. A cubic relationship between GDP and CO_2 was found to fit the data most appropriately; hence the EKC hypothesis was not confirmed.

Taguchi (2012) found that sulphur emissions follow the expected inverted-U shape while CO_2 tends to soar in accordance with the rise in per capita income. Mishra et al. (2015) re-appraised the EKC hypothesis by initializing the role of institutional quality and distributional heterogeneity and running panel quantile regression over the period from 1960 to 2003 for 127 countries. They illustrated that once endogeneity bias is corrected and heterogeneity in the effects of income and institutional quality is introduced, the EKC tends to vanish at higher quantiles of emission. Still, its existence is proven at lower quantiles.

Using CO_2 emissions per capita as the pertinent standard of environmental degradation, Chuku (2011) investigated the income-environment relation for Nigeria between 1960 and 2008. The results from the standard-EKC model provided weak evidence of an inverted-U shaped relationship with a 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.

Omisakin (2009) investigated the relationship between Economic Growth (GDP) and environmental quality in Nigeria. The Environmental Kuznets Curve (EKC) hypothesis is investigated and tested with the annual data of carbon emissions capita and GDP per capita from 1970-2005. The study reveals no causal or long-run relationship between carbon emissions and income in Nigeria. Again, the regression line (curve) gotten from regressing carbon emission on GDP and its square completely refute the EKC hypothesis in the case of Nigeria. Interestingly, the curve depicts a ‘U-shaped’ rather than an ‘inverted U-shaped’ curve (as suggested by the EKC hypothesis), meaning that with increase in income, carbon emission first experiences a declining trend and then starts rising again.

Akpan and Chuku (2011) and Osabuhien et al. (2013) established that a long-run relationship exists between indicators of environmental pollution (CO_2 and Premium motor spirit emissions), per capita income and its square, institutional variable and trade (in Nigeria), thus signifying the probability of selected explanatory variables converging with the environmental pollution in the long run. Alege and Ogundipe (2013) studied the relationship between environmental quality and economic growth in Nigeria using a fractional cointegration analysis over the period 1970 to 2011. The study finds that early stages of development in Nigeria accentuate the level of environmental degradation and fails to attain a reasonable turning point, hence, a non-existence of EKC in Nigeria. Egbetokun et al. (2020) examined the EKC and considered the impact of institutional quality on six variables of environmental pollution (carbon dioxide (CO_2), nitrous oxide (N_2O), suspended particulate matters (SPM), rainfall, temperature and total greenhouse emission (TGH)) using the case of Nigeria. The results indicate that there is EKC for CO_2 and SPM. Other environmental pollution indicators did not exert a significant influence on economic growth.

De Bruyn et al. (1998) adopt a dynamic model and estimate for three types of emissions (CO_2, N_2O and SO_2) in four separate developed countries (Netherlands, UK, US and Western Germany). It is found that these emissions correlate positively with economic growth and that emissions may decline over time, probably due to structural and technological changes. Meyer et al. (2003) conducted a survey on deforestation based on the data of 117 countries and the time span from 1990 to 2000. The finding is a U-shaped curve.

Jin and Kim (2020) examined the environmental Kuznets curve (EKC) relationship through a heterogeneous panel analysis of 34 countries for the 1990 to 2016 period. They confirmed the long-run equilibrium relationship between carbon emissions, trade openness, fossil fuel usage, and GDP through the panel cointegration tests that is robust to cross-sectional dependence. Their overall finding is that the empirical results show no consistent evidence of the EKC hypothesis in countries via mean group and long-run estimation. Country-specific estimation shows that only 5 of the 34 countries support the EKC hypothesis.

Empirical studies have produced mixed results. Multiple country studies employ panel data econometrics, while single-country studies employ time series analysis. However, in recent time there has been a concern about unit roots in panel data too with large datasets. Grossman and Krueger (1995) used panel data analysis to confirm the existence of the Environmental Kuznets Curve. Panel data analysis is subject to criticisms in favor of time series analysis of one country. The panel data approach suggests that all countries will follow the same pollution trajectory and there will be a common EKC among countries, which does not appear to be the case. In addition, panels use a short time span typically. The EKC is essentially a long-term phenomenon since the economy needs time to reach the turning point of the EKC. Among the time-series studies, Perman and Stern (2003) consider sulphur emissions for many countries both at an individual level, and then at a panel level. Using the Engle-Granger (1987) method, they find that a long-run cointegrating relationship only exists in 35 out of 74 countries. Other studies employ the Pesaran et al. (2001) Autoregressive Distributed Lag bounds testing approach to cointegration allowing both I(1) and I(0) variables in the relationship. Ang (2007) confirms the EKC hypothesis with French CO_2 emissions over 1960-2000. He (2008) reports that there is no one-fit-for-all EKC. The turning points found in different studies are strikingly different, even where EKC is confirmed to exist. That implies that individual country studies are worthwhile. Jalil et al. (2010) suggest that a time series analysis for a single country may provide better framework to study the relationship.

Concerning econometric methodology, nonparametric estimation has recently gained popularity. Among the papers that use nonparametric estimation techniques is that of Harbaugh et al. (2002), where they use a nonparametric pooled regression to examine the relationship between a CO_2 environmental efficiency index and GDP per capita for a panel of countries. Their results indicate a U-shaped relationship followed by an inverted U relationship. Bertinelli and Strobl (2005) employed a partially linear model in a cross-country context and found that a linear relationship between per capita income and SO_2 and CO_2 emissions cannot be rejected.

Although many theoretical models can predict the Kuznets U-curve, empirical evidence for the validity of the Kuznets hypothesis is still a matter of controversy. Empirical research on the validity of Kuznets hypothesis was performed by many authors, but obtained results are controversial and not conclusive.

So far, the results from these existing studies regarding the EKC have been mixed and diverse (Nigeria inclusive). Wang et al.. (2013) reported that the EKC has been estimated for a variety of other environmental indicators, including air pollution, water pollution, deforestation, hazardous waste and toxins, carbon dioxide, biodiversity conservation and ecological footprints. Unfortunately, no work has estimated EKC on fluorinated gases. Yet, fluorinated gases are emitted globally exclusively from human-related sources and have a large life span in the atmosphere. These gases are primarily emitted through their use as a substitute for ozone-depleting substances and industrial processes. Sulphur hexafluoride (SF6) especially has a global warming potential that is around 22,800 times stronger than the impact of carbon dioxide (CO_2) over a 100-year time horizon (Tiseo, 2020). Because fluorinated gases tend to remain much longer in the atmosphere than natural greenhouse gases, they are included in the basket of gases controlled by the Climate Change Treaties (DCCAE, 2020).

Nonetheless, this paper aims to empirically investigate the validity of the environmental Kuznets curve in the case of Nigeria using time series data for fluorinated gas emissions and gross domestic product per capita between 1970 and 2018. Nigeria was chosen as a case study because the structure of the Nigerian economy is typical of an underdeveloped country and dominated by pollution-intensive sectors.

Since the early 1960s, Nigeria has been pursued industrialization (Famade, 2007). This was executed via formulation of chains of industrial development policies. Notwithstanding that the level of industrialization in Nigeria is low, it has an impact on economic and social development and generates pressure on the environment. One of the economic gains is the Gross Domestic Product (GDP) in Nigeria which was worth 448.10 billion US dollars in 2019, according to official data from the World Bank and projections from Trading Economics (Trading Economics, 2020). The GDP value of Nigeria represents 0.37 percent of the world economy (Trading Economics, 2020). Also, industrialization resulted in enhanced health care services via manufacture of drugs and other medical ancillaries (UNIDO, 2004).

In the area of environment, the issue of greenhouse gas from continuous gas flaring of multi-national oil companies in the oil sector which the federal government of Nigeria, in spite of various policies, have not been able to cut back (UNIDO, 2004). According to Omotosho (2015), Nigeria does not produce Hydrofluorocarbons (HFCs). As a result, all her requirements (containing HFC) are imported. HFCs are man-made greenhouse gases that are used in air conditioning, refrigeration, as solvents, foam blowing agents, fire suppressants and aerosols. They form one of the major substances used since the 1990s as replacements for chlorofluorocarbons (CFCs) under the Montreal Protocol on Substances that Deplete the Ozone Layer, and are also replacements for HCFCs in a number of applications. The global warming impact of HFCs is strong and if left unchecked, it is estimated that they could account for up to 20 percent of total climate pollution by 2050 (Omotosho, 2015).

Other components (control variables) besides income that may be crucial in ascertaining a country's level of fluorinated gas emissions were also considered. The paper further applies the autoregressive distributed lag model (ADL) which is the major workhorse in dynamic single-equation regressions. This is because static models are often condemned for their gross incapability to account fordecision-making and planning in the long run (Nnyeneime, 2018). This may consequently give rise to phony and erroneous predictions/conclusions about the exact and precise relationship that exists between pollution in relation to the output.

4 Methodology

This paper adopts quantitative methodological framework (time series analysis) in order to capture the relationship between GDP and fluorinated gas emissions. This is because it is a single country (Nigeria) study. The data for this study was obtained mainly from secondary sources; particularly from Index Mundi data portal and relevant literature. The data used cover forty-eight (48) years from 1970 to 2018. This covers the period of Nigeria's industrialization during the independence era, specifically from the era of oil boom (1970-1979), the decade of the 1980s, and 1990 and to when Nigeria signed up to the Paris Agreement, the international deal aimed at tackling climate change. This span of period witnessed increasing emissions of greenhouse gas (GHG) emissions due to human activities, which have led to an increase in atmospheric concentrations of the long-lived GHG gases carbon dioxide (CO_2), CH_4, and nitrous oxide (N_2O), perfluorocarbons PFCs, hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF6) and ozone-depleting substances (ODS; chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs). The rest of issues covered in the methodological section include model specification and estimation technique.

4.1 Model Specification

To examine the relationship between GDP and fluorinated gas emissions (HFC, PFC and SF6) which are by-product emissions of hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride, this study hinges on the theoretical underpinning of the Environmental Kuznets Curve (EKC), which postulates a relation between economic growth and environmental degradation. The EKC hypothesis analysis is identified by various forms such as linear, quadratic, and cubic. The standard reduced-form quadratic equation Environmental Kuznets Curve is specified as follows:

$$Y_t = \beta_0 + \beta_1 X_t + \beta_2 X^2_t + \beta_3 \check{Y} + \varepsilon_t \quad (1)$$

Where: Y= environmental degradation(pollutant); X=GDP per capita; X^2 = square of GDP per capita; $\check{Y}$ = A vector of other variables that often affect the environment(Greenhouse gas emission drivers); t= time; ε=Error term

Hereafter, this paper specifies and estimates the environmental Kuznets curve (EKC) in a logarithm form based on fluorinated greenhouse gas emissions for Nigeria to determine whether the country has an EKC:

$$\log OGH_t = \tilde{\omega}_0 + \tilde{\omega}_1 \log GDP_t + \tilde{\omega}_2 \log GDP^2_t + \tilde{\omega}_3 \log ANE_t + \tilde{\omega}_4 \log CRW_t \, \tilde{\omega}_5 \log FOD_t + \hat{Z}_i \quad (2)$$

Where: OGH = Fluorinated greenhouse gas emissions which are by-product emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), Sulphur hexafluoride (SF6) (measured in thousand metric tons of CO_2 equivalent); GDP = Gross Domestic Product (per capita, current LCU); GDP^2 = Square of per capita GDP; ANE = Alternative and nuclear energy (% of total energy use); CRW = Combustible renewables and waste (% of total energy); FOD = Adjusted savings: net forest depletion (% of GNI); $\tilde{\omega}_0 - \tilde{\omega}_5$ = parameters to be estimated; $\hat{Z}_i$ = Error term.

Based on a priori expectation, if $\tilde{\omega}_1 > 0$, and $\tilde{\omega}_2 = 0$, then, we have the linear case relationship between economic growth and environment. If $\tilde{\omega}_1 > 0$ and $\tilde{\omega}_2 > 0$, it implies monotonically increasing relationship among the variables. Whereas when $\tilde{\omega}_1 < 0$ and $\tilde{\omega}_2 < 0$, the relationship implies monotonically decreeing among the variables. If $\tilde{\omega}_1 > 0$, $\tilde{\omega}_2 < 0$, and, then there will be an inverted-U shaped relationship between environment degradation and GDP. And if $\tilde{\omega}_1 < 0$ and $\tilde{\omega}_2 > 0$ we would have U shaped relationship among the variables. Where $\tilde{\omega}_1$ and $\tilde{\omega}_2$ are the parameter estimates for the levels and square of per capita GDP, respectively. $\tilde{\omega}_3$ - $\tilde{\omega}_5$ are Greenhouse gas emission drivers and expected to impact positively on environmental degradation. In order to avoid spurious regression, this study adopts the Augmented Dickey Fuller Test (ADF) to determine the stationary properties of the variables. Data for the variables were sourced from Index Mundi data portal, Knoema.com and relevant literature and spanned the period 1970 to 2018.

4.2 Estimation Technique

Autoregressive Distributed Lag Model (ARDL) technique plays a key role when faced with making vital economic decision from past data. Change in economic variables may bring change in other economic variables beyond time (Kripfganz and Schneider, 2018). This is termed as changes distributed over future periods. This is a model containing the lagged values of the dependent variable, the current and lagged values of the regressors as explanatory variables. The ARDL model uses a combination of endogenous and exogenous variables. It is often necessary for stationary (unit root) test to be conducted to ascertain that no variable is integrated of order 2 i.e., I(2).

The Auto Regressive Distributed Lags (ARDL) approach to cointegration was adopted in this paper. ARDL bounds testing approach is a cointegration method developed by Pesaran et al. (2001) to test the presence of the long-run relationship between the variables. This procedure, relatively new method, has many advantages over the classical cointegration tests. Firstly, the approach is used irrespective of whether the series are I(0) or I(1). Secondly, an unrestricted error correction model (UECM) can be derived from the ARDL bounds testing through a simple linear transformation. This model has both short and long-run dynamics. Thirdly, the empirical results show that the approach is superior and provides consistent results for small sample.

The general form of the ARDL regression model is as follows:

$$y_t = \beta_0 + \beta_1 y_{t-1} + ...+ \beta_k y_{t-p} + \alpha_0 x_t + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + ... + \alpha_q x_{t-q} + \varepsilon_t \quad (3)$$

*where: y_t : Dependent variable (logOGH$_t$); y_{t-i} : Lag of the dependent variable (logOGH$_{t-i}$); x_t : Independent variable (logGDP$_t$, logGDP^2_t, logANE$_t$, logCRW$_t$, log***FOD**$_t$*); x_{t-i} : Lag of the dependent variable (logGDP$_{t-i}$, logGDP$^2_{t-i}$, logANE$_{t-i}$, logCRW$_{t-i}$, log***FOD**$_{t-1}$*); p : Optimal lag order associated with the dependent variable in years; q : Optimal lag order associated with the independent variable in years; β_0 : Constant; β_i : Coefficient for dependent variable (coefficients for short-run); α_i : Coefficient for Independent variable (coefficient for long-run); ε_t : A random "disturbance" term, which is assumed "well-behaved" in the usual sense. In particular, it will be serially independent.*

5 Discussion of Estimated Regression Results

5.1 Unit root test

Table 1:

Variables	ADF statistics	Critical Value	Order of Integration
LOGGDP	-2.209445	-1.948140**	*I*(1)
LOGOGH	-6.975152	-2.615093*	*I*(1)
LOGGDP2	-2.269286	-1.948140**	*I*(1)
LOGANE	-8.555065	-2.615093*	*I*(1)
LOGCRW	-5.542408	-2.615093*	*I*(1)
LOGFOD	-2.300220	-1.947816**	*I*(0)

Source: Author's computation using eviews software
Note: * Indicates stationary at the 1% level, and ** Indicates stationary at 5% level.

The unit root test results of the incorporated times series variables in the regression model are presented in Table 1. Using Schwarz Info Criterion, maximum lag length of 10 and no intercept or trend and intercept, the traditional test of the ADF here indicates that almost all the variables tend to be stationary in first difference except LOGFOD that was stationary at level. Hence, the series are integrated in of order 1(1) and I(0). This is evidence by the fact that the Absolute Values of the ADF test statistics are all greater than the critical values at the 1% and 5% level of significance. After stationarizing the variables, the data can then be tested whether these variables are co-integrated or not.

5.2 ARDL Regression Result

In applying the Auto Regressive Distributed Lag Models approach to co-integration, the model in equation 2 was estimated in static (level) form by using selecting 2 as the maximum lags of dependent variable and independent variable. The trend specification was constant. The model selection criteria was the Akaike info Criterion (AIC). The result is presented in Table 2.

The output in Table 2 was evaluated and the bounds test was conducted under the hypothesis that:

H_0: no cointegrating equation; H_1: H_0 is not true. Rejection of the null hypothesis is at the relevant statistical level, 10%, 5% level, 1%. The three options of the decision criteria are as follows:

1. If the calculated *F*-statistic is greater than the critical value for the upper bound *I(1)*, then we can conclude that there is cointegration that is there is long-run relationship.
2. If the calculated *F*-statistic falls below the critical value for the lower bound *I(0)* bound, then we conclude that there is no cointegration, hence, no long-run relationship
3. The test is considered inconclusive if the *F*-statistic falls between the lower bound *I(0)* and the upper bound *I(1)*.

The ARDL Bounds Test result is shown in Table 3. The F-statistic for the Bounds Test is 3.111806 and falls between the lower bound I(0)and upper bound I(1). Accordingly, the hypothesis of "no long-run relationship" is rejected. As such, the long-run model was considered.

The result of the long-run relationship in Table 4 shows that the error-correction coefficient (cointEq(-1)) is negative (-0.320354), as required, and is very significant. Importantly, the long-run coefficients from the cointegrating equation are reported, with their standard errors, t-statistics, and p-values. It shows that there's a long-run equilibrium relationship between GDP, GDP^2, ANE, CRW and FOD.

Table 2: Auto Regressive Distributed Lag Result: short-run estimates.

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LOG(OGH(-1))	0.679646	0.093492	7.269597	0.0000
LOG(GDP)	2.451946	11.79962	0.207799	0.8365
LOG(GDP^2)	-1.614875	5.884121	-0.274446	0.7852
LOG(GDP^2(-1))	0.050544	0.248508	0.203390	0.8399
LOG(GDP^2(-2))	0.417603	0.180555	2.312881	0.0262
LOG(ANE)	0.895694	0.321401	2.786840	0.0083
LOG(CRW)	2.116169	1.968668	1.074924	0.2892
LOG(FOD)	0.019150	0.054698	0.350095	0.7282
C	-6.594340	8.612576	-0.765664	0.4486
R-squared	0.924275	Mean dependent var		10.05823
Adjusted R-squared	0.908333	S.D. dependent var		1.309612
S.E. of regression	0.396507	Akaike info criterion		1.158169
Sum squared resid	5.974266	Schwarz criterion		1.512453
Log likelihood	-18.21698	Hannan-Quinn criter.		1.291489
F-statistic	57.97671	Durbin-Watson stat		2.335840
Prob(F-statistic)	0.000000			

Source: Author's computation using eviews software
*Note: p-values and any subsequent tests do not account for model selection.

Table 3: The ARDL Bounds Test Result.

Test Statistic	Value	k
F-statistic	3.111806	5
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

Source: Author's computation using eviews software

A 1% change in GDP will result in a long-run change of OGH by 7.7%. Similarly, a 1% change in GDP^2 will result in a long-run decrease of OGH by 3.6% . This signs of the coefficients are as expected. This shows a sign of an inverted-U shaped relationship between environment degradation and GDP. That means environmental improvements would eventually occur as economy grows. Unfortunately, this relationship is not statistically significant at any of the conventional levels. That means no EKC relationship exist.

In the same vein, the short-run estimates in Table 2 are also correctly signed, still yet, the relationship between environment degradation and GDP is statistically insignificant. As such, for other greenhouse gas emissions

Table 4: Long Run Result.

Cointegrating Form				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
DLOG(GDP)	2.451946	11.799619	0.207799	0.8365
DLOG(GDP^2)	-1.614875	5.884121	-0.274446	0.7852
DLOG(GDP^2(-1))	-0.417603	0.180555	-2.312881	0.0262
DLOG(ANE)	0.895694	0.321401	2.786840	0.0083
DLOG(CRW)	2.116169	1.968668	1.074924	0.2892
DLOG(FOD)	0.019150	0.054698	0.350095	0.7282
CointEq(-1)	-0.320354	0.093492	-3.426553	0.0015
Cointeq = LOG(OGH) - (7.6539*LOG(GDP) -3.5796*LOG(GDP2) + 2.7960				
*LOG(ANE) + 6.6057*LOG(CRW) + 0.0598*LOG(FOD) -20.5845)				
Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(GDP)	7.653867	36.660381	0.208778	0.8357
LOG(GDP^2)	-3.579568	18.319203	-0.195400	0.8461
LOG(ANE)	2.795951	1.125159	2.484939	0.0175
LOG(CRW)	6.605724	6.437921	1.026065	0.3113
LOG(FOD)	0.059776	0.174689	0.342187	0.7341
C	-20.584549	27.933911	-0.736902	0.4657

Source: Author's computation using eviews software

(hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6)), the environmental Kuznets curve (EKC) hypothesis is rejected for Nigeria.

Nonetheless, the result in Table shows 4 (long-run estimates) a positive and significant relationship between other greenhouse gas emission(environmental degradation) and LOG(ANE) (i.e., Alternative and nuclear energy (% of total energy use)). While the short-run estimates in Table 2 also shows a positively significant relationship for LOG(OGH(-1)), LOG(ANE) and LOG(GDP^2(-2)), however, the sign of the coefficient of LOG(GDP^2(-2)) does not align with aprior expectation.

The implication of these results is that even the production of electricity through alternative and nuclear power (LOG(ANE)) give rise to emission which affect the environment though, these being during construction and decommissioning, or mining and fuel preparation. Also, increase in other greenhouse gases (LOG(OGH(-1))) have effects on environment. Such effects, apart from global warming, include ocean acidification, smog pollution, ozone depletion and changes to plant growth and nutrition levels. Another implication of the result is that environmental deterioration is experienced as incomes increase (LOG(GDP^2(-2))) suggesting that developing country like Nigeria is still below the desired income turning point, at which better economic development will lead to reduced environmental damage.

6 Summary, Conclusion and Policy Recommendations

The increasing threat of global warming and climate change has focused attention on the relationship between economic growth and environmental pollutants. Many studies have examined the relationship between environmental degradation and economic growth. The main focus of this line of research has been on the Environmental Kuznets Curve (EKC) or what is called as Carbon Kuznets Curve (CKC) hypothesis. Using the most recent data sets available on Nigeria's emissions of fluorinated greenhouse gas emissions which are by-product emissions of hydrofluorocarbons, perfluorocarbons and Sulphur hexafluoride, this paper aimed to test the applicability of the EKC in Nigeria from 1970-2018. The cointegration analysis using Auto Regressive Distributed Lag (ARDL) bounds testing approach was incorporated and the result shows that there's a long-run equilibrium relationship between GDP, GDP^2, ANE, CRW and FOD. The long-run estimates showed the sign of an inverted-U shaped relationship between environment degradation and GDP. Unfortunately, this relationship was not statistically significant at any of the conventional levels. In the same vein, the short-run estimates were also correctly signed, still yet, the relationship between environment degradation and GDP was statistically insignificant. Invariably, the results do not support the EKC hypothesis both in short-run and long-run and inverted U-shaped relationship was not found between fluorinated greenhouse gas emissions (HFCs, PFCs and SF6), and growth in Nigeria, i.e., economic growth has no impact on environment degradation (fluorinated gases emission).

Interestingly, a positive and significant relationship between fluorinated greenhouse gas emissions (environmental degradation) and LOG(ANE) (i.e., Alternative and nuclear energy (% of total energy use)) was observed in the long-run estimates. While the short-run estimates showed a positively significant relationship for LOG(OGH(-1)), LOG(ANE) and LOG(GDP^2(-2)), however, the sign of the coefficient of LOG(GDP^2(-2)) did not align with aprior expectation.

Conclusively, this study has found no relationships at all between income per capita represented by Gross Domestic product per capita and fluorinated gases (pollutant) in Nigeria. That means it does not validate the existence of the EKC hypothesis in Nigeria for fluorinated gases. Although fluorinated gases are emitted in smaller quantities than other greenhouse gases but they have a high global warming potential and since some pollutants (such as fluorinated gases emission) tend to rise with income increase hence are increasing functions of income and subsequently, damages caused by these pollutants may not be reversible if pollutants tend to be accumulated in forms of stocks over a period of time. According to Denchak (2019), the global warming potential (GWP) for fluorinated gases can be in the thousands to tens of thousands, and they have long atmospheric lifetimes, in some cases lasting tens of thousands of years. The use and emissions of fluorinated gases have been increasing and are foreseen to increase even more rapidly if no steps are taken to control them. This paper is of the view that there are extensive opportunities to fluorinated gas emissions using existing technology and alternative substances with low global warming potential. As such, industrial users of fluorinated gases in Nigeria (or elsewhere) can reduce emissions by adopting fluorinated gas recycling and destruction processes, optimizing production to minimize emissions, and replacing these gases with alternatives. For instance, in Switzerland, the use of HFC-134a substance in refrigerators is banned and climate-neutral hydrocarbons are used instead (EMPA, 2012). The German Federal Environmental Agency (UBA) proposes a placing on the market prohibition of fire protection systems and fire extinguishers containing HFC23 as already in force for perfluorocarbons (GFEA, 2011).

To also reduce the uses and emissions of HFC in Nigeria, government should establish and strengthen the political, institutional and regulatory framework for the gradual reduction of HFC, including the development of an integrated strategy with other appropriate strategies; example: implement a national import and export licensing regime. This would help in regulating or banning the importation of refrigeration and stationary air-conditioning which emits HFCs. There is a rapidly increasing demand for refrigeration and cooling services, particularly in developing countries like Nigeria, and this could increase fluorinated gas emissions considerably. In the same vein, government should raise awareness among the main actors: decision-makers, industrialists, end-users and investors.

Since unbridled power generation and developmental activities in Nigeria have led to unquantifiable environmental devastation, the suggestion in this paper is that policies promoting more alternative source of energy with very little or no emission of greenhouse gases should be adopted and implemented in the country. For example, gas to liquid fuel which can tackle emission from diesel vehicles, **hydrogen fuel additives which can** reduce emissions by improving the fuel combustion cycle in existing vehicles through the use of additives. In the same vein, technologies should be deployed that can remove pollution from the ambient air. For example, photo-catalytic treatment that can remove pollutants from the air in the presence of sunlight. This treatment can be applied to a range of surfaces like roofing tiles, roads, etc.

Limitation and Further Research: The unit roots tests performed in this study did not account for structural breaks in the data. In the case of Nigeria, it is particularly reasonable to expect a structural break, given the change from military rule to democracy. To this end, further research should aim at analyzing the EKC by considering all possible shifts (structural breaks) in estimated parameters.

Financial Support: This research received no specific grant from any funding agency, commercial or nonprofit sectors.

Conflict of Interests Statement: The authors have no conflicts of interest to disclose.

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