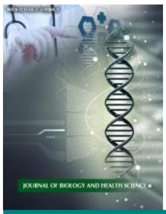

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Review Article

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The Impact of Renewable Energy Sources and Economic Growth on the Environmental Quality in Nigeria

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Abstract

Renewable energy sources, such as solar, wind, geothermal and hydropower, have the potential to drive economic growth without compromising environmental quality. However, many studies have examined renewable energy consumption as a whole, with little focus on the individual effects of different renewable energy sources that are most relevant to Nigeria's economic and environmental landscape. This study aims to analyze the impact of specific renewable energy sources and economic growth on environmental quality in Nigeria, using a time-series dataset spanning from 2000 to 2022.The findings reveal that a one-unit increase in per capita GDP leads to a rise in the ecological footprint per person by 2.59×10^{-4} units, while a one-unit increase in per capita squared GDP reduces the ecological footprint per person by 4.21×10^{-8} units. This confirms the Environmental Kuznets Curve (EKC) hypothesis, indicating that economic growth initially worsens environmental quality but improves it at higher income levels. Additionally, a one-unit increase in solar energy reduces the ecological footprint per person by 2.07×10^{-3} units, though the effect is not statistically significant. Conversely, a one-unit rise in hydropower consumption increases the ecological footprint per person by 2.5×10^{-5} units, suggesting potential environmental concerns associated with hydropower use. Furthermore, a one-unit increase in Human Capital Development (HCD) leads to a reduction in the ecological footprint per person by 4.99 units, emphasizing the role of education and skill development in promoting environmental sustainability. Overall, the study concludes that economic growth initially harms environmental quality but later contributes to its improvement. While solar energy does not show a significant environmental impact, hydropower consumption and human capital development play a more pronounced role in shaping environmental outcomes in Nigeria.

Keywords: Renewable energy; Economic growth; Environmental quality; Solar; Hydro; Human capital development; Nigeria

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Introduction

Globally, environmental concerns have received a lot of attention among researchers and scholars. Concerns about climate change are now prevalent, as a result of excessive greenhouse gases emissions, which are dominated by CO_2. Anthropogenic sources which include deforestation and the burning of fossil fuels (coal, petroleum and natural gas) are the major contributors to greenhouse gases which in turn bring about global warming. A study conducted by demonstrated that the decline of the environment is a result of growth in the economy, particularly in developing economies as they strive to improve their economies [1]. In the context of EKC theories, some researchers have looked at the link between environmental deterioration and growth in the economy the findings of this research have been conflicting; nonetheless, some have concluded that there is an inverse U-shaped association that is consistent with the EKC theory between environmental deterioration and growth of the economy, other findings

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found no proof of an EKC relationship [2-4]. In particular, a reverse U-shaped connection says that environmental deterioration rises with income, whereas a U-shaped relationship suggests that environmental pollution falls with income. Lastly, an N-shaped relationship indicates that there is little chance of the original EKC theory to persist over time since, above a certain income threshold, income growth may once more result in a positive association between environmental degradation and the growth of the economy [5]. Concerns to raise the proportion of renewable energy sources in the global energy mix are growing [6].

Economic growth is frequently linked with environmental degradation; The utilization of renewable energy sources is acknowledged as a means to alleviate the adverse environmental consequences typically associated with economic growth. Nigeria's economy is expanding quickly and uses a lot of renewable energy, be that as it may, the nation also has to deal with a multitude of environmental issues. To discover potential policy interventions that can help promote economic growth while also safeguarding the environment this study is very vital. Much attention has been given to renewable energy consumption as a whole with little reference to separating each of the types of renewable energy that are more economical and environmentally peculiar to Nigeria hence it can be said that this component represents a gap [1,2,4,7-10]. This study is therefore designed to separate each renewable energy source as it affects environmental quality.

The link between environmental well-being and human capital in Nigeria and Africa, in general, has received minimal attention about the role human capital plays in environmental sustainability. Nigeria's fast population growth points to both increased environmental strain and public spending on human capital (health and education). The knowledge, skills and capacities of a people are referred to as human capital. It plays a vital role in the growth and progress of the economy, with significant potential for environmental conservation. A well-educated and skilled population is more inclined to adopt and utilize renewable energy technologies, as well as support environmental policies. When examining the interplay between energy, the environment and economic development in Nigeria, it is imperative to factor in human capital for various reasons. Firstly, Nigeria's large and youthful population presents a substantial opportunity for human capital development. Secondly, Nigeria's economy, a country that is fast developing, is mostly reliant on fossil fuels. This is why it's critical to figure out how to lower environmental pollution and switch to a more sustainable energy mix. Third, Nigeria is dealing with a diverse range of environmental issues, including water pollution, climate change and pollution in the air, developing human capital can be essential to overcoming these obstacles. Research conducted in other countries has also examined this relationship; these studies include [11-14]. All of these studies concur that developing human capital is crucial to environmental sustainability because it reduces emissions from fossil fuels. This research will examine the connection between these variables in Nigeria to better understand the potential for renewable energy to help enhance the country's environmental quality.

The need to achieve sustainable development on a worldwide scale has prompted a heightened emphasis on the intricate connection between the utilization of renewable energy, economic growth and environmental well-being. The Environmental Kuznets Curve (EKC) theory suggests that environmental degradation tends to worsen as economies grow but starts to improve after reaching a certain income threshold. Although this idea has been discussed and examined extensively in a variety of settings, its application is still up for debate.

Nigeria, an African country that is developing quickly, has seen significant economic growth as well as an increase in its reliance on renewable energy sources as part of its energy transition plan. It does, however, also confront serious environmental issues, including biodiversity loss, air and water pollution and deforestation. Evaluating whether the EKC hypothesis is valid in the Nigerian context and whether the growing use of renewable energy sources is consistent with a possible reversal of environmental degradation is therefore crucial. To this end, the study addresses the following research questions; What impact does each of the renewable energy sources have on Nigeria's environmental quality? How does human capital development affect environmental quality in Nigeria? Is the EKC hypothesis valid in Nigeria?

Brief Empirical Review

Using developing economies in Sub-Saharan Africa as a case study, investigated the effects of growth in the economy, urbanization and the use of non-renewable energy sources, solid fuels and clean energy on environmental degradation [15]. According to the findings, the use of fossil fuels and solid fuel for cooking as well as the growth of metropolitan regions both greatly increase CO_2 emissions and promote air pollution. The findings also show that the connection between CO_2 emissions and per capita economic development is shaped like an inverted U. This relationship demonstrates that middle-class and lower-class economies in Sub-Saharan Africa have an Environmental Kuznets Curve (EKC). Additionally, the results show that using renewable energy options reduces direct household exposure to harmful gasses and controls carbon emissions, both of which enhance air quality. In a study conducted by Asongu et al. they explored the connection between using renewable energy and environmental degradation in Sub-Saharan Africa [7]. They found that the use of renewable energy consistently leads to a reduction in carbon dioxide (CO_2) emissions, as indicated by both estimation methods. Additionally, when comparing countries with higher CO_2 emissions to those with lower emissions, the negative environmental impact is less pronounced in the former. The study conducted by

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Abubakar and Dan 2020 examined the impact of energy use on Nigeria's environmental quality, using CO_2 emissions as evidence. Results indicated that whereas fuel wood usage has a long-term potential to increase CO_2 emissions, charcoal consumption has a long-term tendency to decrease CO_2 emissions. From 2001 to 2018, Syed et al. looked at the relationship between renewable energy use and environmental quality and international trade in Nordic countries. The results showed that in Nordic nations, renewable energy has a high and favorable correlation with international trade. Additionally, the data show that environmental quality improves with the consumption of renewable energy. examined the nexus between Nigeria's environmental quality and renewable energy consumption: The impact of broad-based financial growth [2]. The findings show that while financial development harms the environment, while renewable energy usage enhances environmental quality. Additionally, the findings support Nigeria's inverted U-shaped connection between environmental deterioration and economic growth.

According to Ojonugwa the research included structural breaks to ascertain the role it plays in the link between economic development and renewable energy usage on the environmental quality in Nigeria [1]. Based on the findings, environmental deterioration is slowed down by renewable energy, but it is accelerated by economic expansion. In the presence of structural fractures, the data further support the EKC concept in Nigeria.

Method

Theoretical framework

The objective of the study is to analyze the impact each renewable energy source and economic growth have on the environmental quality in Nigeria. Hence this study adopts the Environmental Kuznets Curve (EKC) Theory propounded by Grossman and Krueger 1991, as it provides an avenue for linking renewable energy consumption, economic growth and environmental quality [16].

According to the EKC theory, environmental pressure or resource use first increases with GDP but, after a certain threshold income level, declines with per capita GDP. This is so that a nation has more resources to devote to environmental preservation when its economy expands. However, a nation may prioritize economic development over environmental conservation in the early phases of its economic expansion.

Data description and model specification

In order to construct the empirical model for the research, it is evident from the literature that multiple investigations have examined the relationship between environmental pollution and economic growth in the framework of the EKC hypothesis. The body of research takes the stance that, in many nations, the vigorous pursuit of economic growth and development a tactic used to reduce poverty is to blame for the degradation of environmental quality. The demand for energy rises when economic growth policies are implemented, which may be detrimental to the environment's quality. In this study, Nigeria's scenario is thoroughly evaluated by integrating renewable energy sources into the environmental quality equation through the use of the EKC model. To this extent, the functional form of the EKC model with incorporation of each of the various renewable energy sources is expressed as follows:

$$EFP=f\,(GDP, GDP2, SOLAR, HYDRO, HCD) \ldots (1)$$

where the EFP measures environmental quality through ecological footprint, GDP measures per capita income, solar energy and hydro energy measures each of the renewable energy sources. The GDP squared is obtained from taking the squared term of the income per capita to determine whether the EKC is an inverted U-shape or simply a U-shape.

Transforming the equation (1) into linear expression provides the empirical model for this study, which is given as follows:

$$EFPt= \alpha0+\alpha GGDPt+\alpha G2GDP2t+\alpha SSOLARt +\alpha HHYDROt + \alpha HDHCDt+ \varepsilon t \ldots\ldots (2)$$

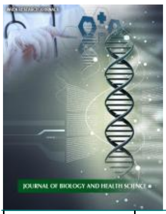
From equation (2), it is clear that the EFP denotes the measure of environmental quality. GDP and GDP squared are per capita income level and its squared term and ⍰ is the stochastic or error term that is invariably assumed to have possessed a zero mean. Renewable Energy (RE) is divided into two sources which include solar and hydro, human capital development is denoted by HCD.

Data sources

The data used in the study is secondary data. This means it has already been collected through primary sources and made readily available for use. It is a time series data with an annual frequency which spans from 2000 to 2022. The data used were sourced from reliable sources such as Global Footprint Network (GFN), World Development Indicator (WDI), Penn World Table and International Energy Agency (IEA). **Table 1** provides full details of variables and their sources.

Table 1: Variables and their sources.

Variable	Acronym	Unit of measurement	Source
Environmental quality (ecological footprint)	EFP	The ecological footprint index, including built-up land grazing land cropland forestland carbon footprint and fishing grounds, is measured in global hectares (gha) per person.	Global Footprint Network (GFN 2018)
Economic growth	GDP	Gross domestic product per capita (constant 2010 US$)	World Develo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			pment indicator (World Bank 2018)
Solar energy source	SOLAR	Gigawatt hours (equivalent to one million kilowatt hours) per capita	International Energy Agency (IEA 2020)
Hydro energy source	HYDRO	Gigawatt hours (equivalent to one million kilowatt hours) per capita	International Energy Agency (IEA 2020)
Human capital development	HCD	Index of human capital, based on years of schooling and returns to education	Penn World Table (PWT 9.1 2019)

Results and Discussion

Pre-estimation results

In this study, the unit root analysis employed two distinct methodologies: The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. This was done to confirm that all the variables under consideration exhibit integration. A variable is considered integrated when it lacks a unit root issue, meaning its mean and variance do not exhibit a time-dependent relationship. The findings in **Table 2** reveal that all variables are indeed integrated at the first order [1]. This result holds true for both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests and is statistically significant at the 1% and 5% levels. Both unit root test reports the stationarity of the variables in their level and first difference forms.

Table 2: Unit root stationary test.

	ADF		PP	
Variables	**Level (0)**	**First difference (1)**	**Level (0)**	**First difference (1)**
EFP	0.102569 (0.9585)	-4.523304*** (0.0020)	0.000866 (0.9490)	-4.523795*** (0.0020)
GDP	-1.830354 (0.3569)	-3.271515** (0.0297)	1.810573 (0.3658)	-3.271515** (0.0297)
GDP2	-1.932909 (0.3119)	-3.304022** (0.0278)	-1.575689 (0.4777)	-3.329712** (0.0264)
SOLAR	0.427458 (0.9795)	-4.892780*** (0.0009)	0.669412 (0.9884)	-4.892780*** (0.0009)
HYDRO	-1.755385 (0.3913)	-5.130601*** (0.0005)	-1.737974 (0.3994)	-5.139133*** (0.0005)
HCD	-0.899423 (0.7679)	-3.714089** (0.0117)	-1.542470 (0.4940)	-3.764661** (0.0105)

Note: * indicates p<10%, ** indicates p<5%, *** indicates p<1%

Table 3 displays the results of the Johansen cointegration test for each variable, which we did prior to estimating the long-run result. The Johansen test permits more than one cointegrating association, in contrast to the Engle-Granger test [17]. Errors that are passed over to the subsequent step can be avoided by using the test to determine the cointegration of multiple time series. We set K0 to zero to see if the null hypothesis would be rejected when performing the trace test to check for cointegration in the sample. We can conclude that there is a cointegration relationship in the sample if it is rejected. Consequently, in order to verify if there is a cointegration connection in the sample, the null hypothesis needs to be rejected. We may move further with the long-run regression analysis as the Johansen cointegration test result indicated that the models are cointegrated.

Table 3: Cointegration test.

Unrestricted cointegration rank test (Trace)				
Hypothesized	-	Trace	0.05	-
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob**
None*	0.963250	163.4497	95.75366	0.0000
At most 1 *	0.905749	94.07355	69.81889	0.0002
At most 2	0.629600	44.47595	47.85613	0.1003
At most 3	0.496189	23.61935	29.79707	0.2170
At most 4	0.325045	9.222725	15.49471	0.3452
At most 5	0.045023	0.967426	3.841466	0.3253

FMOLS regression result

Table 4 presents the FMOLS long-run coefficients of the environmental quality function. The results indicate that Per capita GDP (GDP) has a positive and statistically significant impact on the Ecological Footprint per Person (EFP), while the squared term of per capita GDP (GDP^2) has a negative and statistically significant impact. Specifically, a one-unit increase in per capita GDP leads to a rise in EFP by 2.59×10^{-4} units, indicating that economic growth initially worsens environmental quality. However, a one-unit increase in per capita squared GDP leads to a decline in EFP by 4.21×10^{-8} units, suggesting that after a certain income threshold, economic growth begins to improve environmental quality. These results confirm the Environmental Kuznets Curve (EKC) hypothesis for Nigeria, meaning that environmental degradation first increases with economic growth but later declines as the economy matures. This finding aligns with previous research, such as Usman et al. 2019 for India, Usman et al. 2020c for South Africa, Usman et al. 2019 for Singapore and Ali et al. 2021 for Nigeria [9,18,19].

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Table 4: Results of FMOLS long-run coefficients.

Variable	Coefficient	Std. error	T-statistic	Prob.
GDP	0.000259***	7.42E-05	3.492275	0.003
GDP2	-4.21E-08**	1.70E-08	-2.4743	0.0249
SOLAR	-0.00207	0.001341	-1.54223	0.1426
HYDRO	2.50E-05**	8.91E-06	2.80263	0.0128
HCD	-4.990827***	1.060214	-4.70738	0.0002
C	3.016109***	0.443213	6.8051	0
Note: * indicates p < 10%, ** indicates p < 5%, *** indicates p < 1%				

The results further reveal that solar energy has a negative but statistically insignificant effect on environmental degradation. A one-unit increase in solar energy reduces EFP by 2.07×10^{-3} units, suggesting that while increased solar energy consumption is associated with lower environmental degradation, the effect is not strong enough to be conclusive. This aligns with findings by Parkman 2020, Destek and Aslan 2020, who observed a similar negative but statistically insignificant effect of solar energy on emissions reduction efforts in India [20,21].

In contrast, hydropower energy has a positive and statistically significant impact on the ecological footprint, indicating that increased hydropower consumption contributes to environmental degradation in Nigeria. A one-unit increase in hydro energy raises EFP by 2.5×10^{-5} units, which suggests that while hydropower is a renewable energy source, its expansion might have unintended environmental consequences. This finding is consistent with Andrei et al. (2019), who found that the construction of hydropower plants in Ecuador led to a decline in ecosystem services value, highlighting the potential environmental costs associated with hydropower projects.

Lastly, the results indicate that Human Capital Development (HCD) has a negative and statistically significant impact on environmental degradation. A one-unit increase in HCD leads to a reduction in EFP by 4.99 units, suggesting that investment in education and skill development fosters environmental awareness and promotes sustainable practices. This result aligns with the findings of Wang et al. which demonstrated a negative correlation between human capital and ecological footprint, implying that a well-educated and skilled workforce contributes to better environmental management [22].

Table 5 presents results for the relationship between the Ecological Footprint (EFP) and several other variables, including Gross Domestic Product (GDP), Human Capital Development (HCD), Solar Energy (SOLAR) and Hydro Energy (HYDRO). The Granger causality test examines whether past values of one variable help predict another variable in a time series setting.

Table 5: Granger causality analysis.

Null hypothesis	Obs	F-statistic	Prob.
GDP does not granger cause EFP	21	9.05861***	0.0023
EFP does not granger cause GDP		0.54633	0.5895
GDP2 does not granger cause EFP	21	6.69405***	0.0077
EFP does not granger cause GDP2		0.70426	0.5092
SOLAR does not granger cause EFP	21	2.13172	0.1511
EFP does not granger cause SOLAR		1.73521	0.2079
HYDRO does not granger cause EFP	21	0.53134	0.5978
EFP does not granger cause HYDRO		3.29203*	0.0635
HCD does not granger cause EFP	21	9.01094***	0.0024
EFP does not granger cause HCD		1.97317	0.1714
Note: * indicates p < 10%, ** indicates p < 5%, *** indicates p < 1%			

The test finds strong evidence (p=0.0023; F-statistic=9.05861, significant at 1%) that GDP Granger causes EFP. However, EFP does not Granger cause GDP (p=0.5895). This means that past GDP values can predict future EFP, but changes in EFP do not predict GDP.

Similarly, GDP^2 Granger causes EFP (p=0.0077, significant at 1%), while EFP does not Granger cause GDP^2 (p=0.5092). This suggests that GDP, even when squared, plays a strong role in explaining variations in the ecological footprint.

There is no significant Granger causality between SOLAR and EFP in either direction (p=0.1511 and p=0.2079). This suggests that solar energy use does not significantly impact the ecological footprint, nor does the footprint influence solar energy usage.

HYDRO does not Granger cause EFP (p=0.5978); however, EFP weakly Granger causes HYDRO (p=0.0635, significant at 10%). This indicates that changes in the ecological footprint might influence hydro energy consumption to some extent, but hydro energy itself does not predict EFP.

Finally, HCD Granger causes EFP (p=0.0024, significant at 1%), while EFP does not Granger cause HCD (p=0.1714). This suggests that improvements in human capital (*e.g.,* education, skills) can predict changes in the ecological footprint, but the ecological footprint does not significantly impact human capital development.

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Conclusion and Policy Recommendation

The study investigates the impact of economic growth and various renewable energy sources on environmental quality in Nigeria over the period from 2000 to 2022. Its primary objectives are to assess the environmental effects of specific renewable energy sources, namely solar energy and hydropower, to evaluate the role of human capital development in environmental quality and to test the validity of the Environmental Kuznets curve (EKC) hypothesis for Nigeria.

To achieve these goals, the study employs econometric techniques, particularly Fully Modified Ordinary Least Squares (FMOLS) regression, following preliminary tests for stationarity and cointegration, including the Augmented Dickey-Fuller Test (ADF) and Phillips-Perron (PP) tests, as well as the Johansen cointegration tests.

The empirical results from the Fully Modified Ordinary Least Squares (FMOLS) regression confirm the EKC hypothesis, showing that economic growth initially worsens environmental quality but improves it at higher income levels. Specifically, per capita GDP has a positive and significant impact on environmental degradation, while its squared term is negative and significant, indicating an inverted U-shaped relationship.

The findings also reveal that hydropower consumption has a significant positive impact on environmental degradation, suggesting that its expansion may contribute to ecological harm. However, Granger causality results indicate that the ecological footprint weakly influences hydro energy consumption, but hydro energy does not significantly drive changes in the ecological footprint. This suggests the need for sustainable hydropower management.

Solar energy shows a negative relationship with environmental degradation in the FMOLS results, but this effect is not statistically significant. This implies that while solar energy has the potential to improve environmental quality, further research is needed to confirm its long-term impact.

Additionally, the study finds that human capital development significantly improves environmental quality. This highlights the importance of investing in education and skill development programs that promote sustainable practices and green technology adoption.

Policy recommendations

Based on these findings, the following policy recommendations are proposed:

Encourage sustainable economic growth

- The government should implement policies that balance economic expansion with environmental sustainability.
- Investing in cleaner technologies and enforcing environmental regulations can help mitigate the negative effects of industrial growth on ecological quality.

Sustainable hydropower development

- Since hydropower significantly contributes to environmental degradation, policies should focus on sustainable hydropower projects that minimize ecological harm.
- Environmental impact assessments should be mandatory for all new hydropower projects.
- Investments in modernizing existing hydro plants to reduce emissions and ecological damage should be prioritized.

Promote the Adoption of Solar Energy

- While solar energy shows promise for reducing environmental degradation, its impact is not yet statistically significant.
- The government should offer incentives such as tax breaks, subsidies and low-interest loans to encourage large-scale solar adoption.
- Further research and development (R&D) into improving solar energy efficiency should be supported.

Invest in human capital for a green economy

- As human capital development significantly improves environmental quality, the government should increase funding for education and training programs focused on renewable energy, sustainability and environmental protection.
- Green job training initiatives should be established to equip workers with skills needed for eco-friendly industries.
- Public awareness campaigns should be launched to promote sustainable consumption and lifestyle choices.

By implementing these policy measures, Nigeria can achieve sustainable economic growth while improving environmental quality, ensuring long-term ecological and economic stability.

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