Energy Mix for Energy Transition: Role of Renewable Energy in Nigeria

Hilili Margaret Johnson[1], Pennap Nanfa Hamisu[1], Babangida Hassana Umar[1] [a], Wilfred Mwakapwa[1]

[1] Research, Central Bank of Nigeria, Nigeria

Energy RESEARCH LETTERS

Given Nigeria's commitment to attain net-zero carbon emissions by 2060, this study presents an optimal energy mix for attaining Nigeria's energy transition goals. The results of the threshold analysis methodology showed that Nigeria's energy mix has a threshold level of 1.3397 per cent, below which an increase in renewable energy production will result in a significant increase in carbon emissions. Given the current high cost of adopting renewable energy sources, transition fuels such as natural gas and LNG could be utilized. Furthermore, joint efforts between monetary and fiscal authorities are needed to reduce the country's carbon footprint.

I. Introduction

Energy is a pivotal driver of global development across various socio-economic levels. The rise in fossil fuels as a primary energy source since the late 19th century has empowered industrialization, transportation, consumer goods production, and heating worldwide. Nevertheless, the widespread reliance on fossil fuels has led to climate change, resulting in global temperature and weather pattern shifts.

Globally, countries have committed to reduce greenhouse gas emissions in response to the urgency of redeeming climate change. This commitment culminated in the 2015 Paris Climate Agreement, which aimed to limit global temperature to below 2℃ above pre-industrial levels with a stronger ambition to stay below 1.5℃ (Maizland, 2022). Additionally, many nations, including Nigeria, have pledged to transition to greener, more sustainable energy sources, such as solar, wind, and hydropower.

Nigeria, a signatory of the Paris Agreement, has set ambitious targets, including an unconditional 20% emissions reduction by 2030 and a revised conditional 47% emissions reduction pledge. Additionally, Nigeria aspires to achieve carbon neutrality by 2060, supported by policies like the Energy Transition Plan and the Climate Change Act of 2021.[1]

To attain these climate goals, Nigeria must determine its optimal energy mix. This study employed a threshold regression analysis to investigate the energy mix, examining the balance between non-renewable and renewable energy sources and their impact on carbon emissions. This study's objective is to identify the point at which increased non-renewable energy consumption becomes unsustainable and hinders the country's energy transition objectives.

Despite their low adoption, renewable energy technologies, including solar power, wind, hydropower, bioenergy, geothermal energy, and ocean energy, can provide a significant proportion of the world's energy needs (Saidur et al., 2010). To significantly reduce greenhouse gas emissions, the share of renewable energy sources must be more than 60 per cent of the global energy mix to reach the milestones in Net Zero Emissions by 2050 (International Energy Agency, 2021). Thus, strategies can be adopted to reduce carbon (CO_2) emissions. Metcalf (2019) explored the role of carbon pricing mechanisms and national emissions targets in facilitating deep decarbonization, and Stokes (2013) provided an overview of policy instruments used to support renewable energy deployment, including feed-in tariffs, auctions, and tax incentives such as investment tax credits and tax exemptions. Notably, renewable energy sources provide opportunities including job creation, energy access for remote areas, and enhanced energy efficiency.

In the domestic space, while some studies have explored the adoption, potentials, and challenges of renewable energy in Nigeria (Nwosu & Anyanwu, 2021; Oyedepo et al., 2020), others have conducted a comprehensive review of Nigeria's renewable energy development (Adegboyega et al., 2019; Anyanwu & Ajayi, 2018). However, all these studies were largely descriptive and review-based.

1   Nigeria's Climate Change Act (2021), explanatory-memorandum-on-nigeria-s-climate-change-acr_6c83884695bbf609fcd795a49d196e89.pdf (climatepolicyradar.org).

Consequently, our study employed an empirical approach to examine Nigeria's need to transition to renewable energy sources. To the best of our knowledge, this study is the first to estimate Nigeria's optimal energy mix. More so, it is the first use of the threshold analysis methodology for Nigeria, based on Bassongui et al.'s (2021) work, which focused on sub-Saharan countries. This methodology provides a framework to capture nonlinear relationships and abrupt shifts in the energy mix, which are essential for understanding the complexities of energy transition dynamics.

The remainder of this paper is structured as follows: Section II details the data sources and methodology used in the analysis. Section III presents and discusses the results. Finally, Section IV concludes the study and offers policy recommendations.

II. Data and Methodology

We obtained annual data from the World Bank database (1990–2022) on carbon emissions per capita, fossil fuel and renewable energy production (quad Btu), Gross Domestic Product (GDP) per capita in local currency, and urban population growth. The annual data was then converted into quarterly series using the quadratic sum function to provide a more detailed analysis. Finally, we computed energy mix as the share of renewable energy (fossil fuel) production to the total energy production. Although some studies computed energy mix as the share of energy consumption (Bassongui et al., 2021; Gielen et al., 2019), this study found energy production to be more relevant, as it is often more directly influenced by government policies, incentives, and investments. Thus, tracking the share of renewable energy in production aligns with policy goals aimed at increasing the use of renewable sources in the energy mix.

Based on this study's objective, we employed a threshold regression model to examine nonlinear relationships between our variables. Specifically, we investigated changes in the dependent variable (carbon emissions per capita) based on the value of our threshold variable (energy mix) by allowing the coefficients of our explanatory variables to differ across threshold levels. The approach recognizes that different energy mixes may have varying impacts on carbon emissions, and the relationship may be nonlinear and characterized by distinct regimes.

We specified our model based on Tong's (1983) work as follows:

$$\ln \Delta(co2) = \alpha_1 + \beta_1 ln\Delta(renewg) + \beta_2 ln\Delta gdppc + \beta_3 upopg + \varepsilon_i, \quad (1)$$
$$re\_mix \leq \gamma_0$$
$$\Delta \ln(co2) = \alpha_2 + \delta_1 ln\Delta(renewg) + \delta_2 ln\Delta gdppc + \delta_3 upopg + \varepsilon_i, \quad (2)$$
$$re\_mix \geq \gamma_0$$

Where re_mix (energy mix) is the threshold variable, and γ_0 is the true threshold value. $\Delta \ln(co2)$ and $ln\Delta(renewg)$ represent the log difference of our dependent variable namely carbon emissions per capita, and our region dependent variable named renewable energy production. Meanwhile, our region independent variables are the log difference of GDP per capita named $ln\Delta gdppc$ and the urban

population growth rate is $upopg$. Finally, ε_i represents the error term which captures unobserved factors that influence carbon emissions. Notably, equations 1 and 2 show the relationship between our dependent and independent variables when the energy mix is below and above a certain threshold.

III. Results and Discussion

In conducting our analysis, we initially checked for evidence of non-linearity in our threshold variable (energy mix) to confirm the appropriateness of using a threshold regression. Figure 1 shows clear evidence of non-linearity in the energy mix as depicted in its spread around the Lowess curve, which confirms the validity of using a threshold regression.

Next, we used the log differences of our variables to attain stationarity in our series, as confirmed by the Dickey-Fuller test. Consequently, we run a threshold regression, as in equations 1 and 2, using the Bayesian Information Criterion (BIC), to select the optimal number of thresholds from a maximum of three (3) thresholds, where the optimal threshold is one (1) (see Table 1).

Our results indicate a threshold level of 1.3397 per cent, below which an increase in renewable energy production will result in a significant increase in carbon emissions. Specifically, when the energy mix is less than or equal to 1.3397 per cent, a 1 per cent increase in renewable energy production would result in a 0.29 per cent increase in carbon emissions. However, as the energy mix exceeds the threshold level, increased production of renewable energy would result in a significant decrease in CO_2 emissions by 0.51 per cent. Our findings align with established expectations and corroborate the conclusions in previous research. Chen et al. (2019) and Saleem et al. (2022) have observed a similar relationship and asserted that a higher proportion of renewable energy production translates into diminished carbon emissions.

Our results indicate that growth in GDP per capita contributes significantly to carbon emissions by about 0.78 per cent; this may be due to increased energy consumption and industrial production from fossil-fuel based energy sources (Alaganthiran & Anaba, 2022; Sikder et al., 2022). On the other hand, growth in urban population results in a significant decline in carbon emissions, due to more energy efficient infrastructure in urban areas (Luqman et al., 2023; Sun & Huang, 2020).

To further buttress the validity of our results, we conducted a granger causality test to ascertain our variables' effects on carbon emissions (see Appendix 1). The test indicated that GDP per capita, urban population growth, and energy mix granger cause carbon emissions. Our results posit that over a 12-year period, Nigeria's energy mix consisted of averagely 1.09 per cent renewable energy, which was below the optimal threshold mix of 1.3397 per cent and the current global energy mix of 4 per cent (Figure 2).
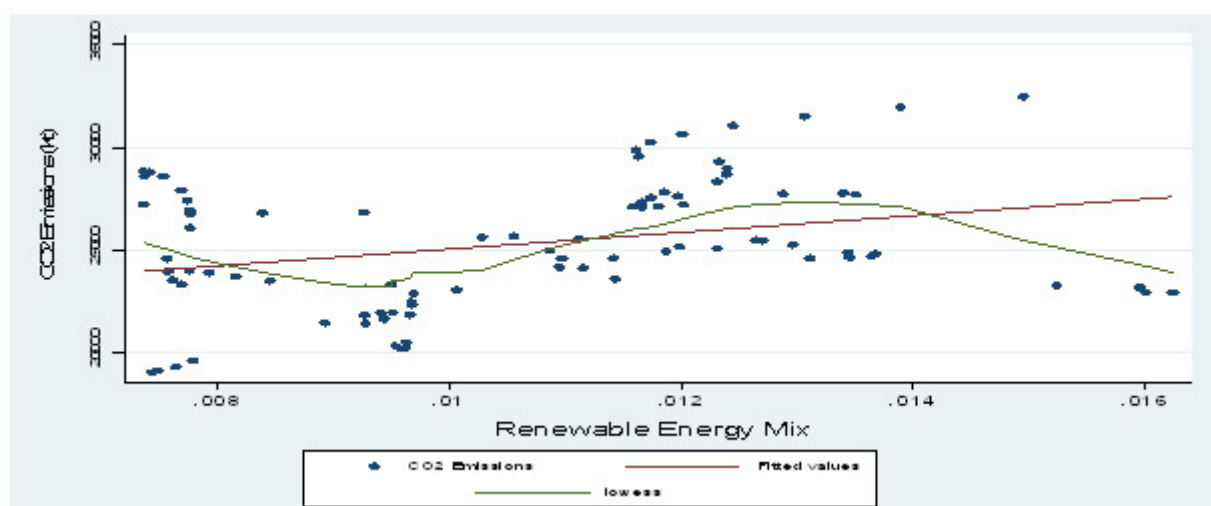
Figure 1. Carbon Emissions and Energy Mix (Lowess Smoothing)

Source: Authors' Computation

Table 1. Threshold Regression Estimation Results

Threshold variable	Energy mix	
Threshold Estimate	1.3397	
Threshold independent variables	$upopg$	-5.2589**
	$ln\Delta gdppc$	0.7828***
	<= Threshold Estimate	>= Threshold Estimate
$ln\Delta(renewg)$	0.2884***	-0.5085***
Observations	131	
Sample	1990Q2 – 2021Q4	

Note: * Indicates significance at 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.

Where $upopg$ is growth in urban population; $ln\Delta gddpc$ is the log difference of GDP per capita; and $ln\Delta renewg$ is the log difference of renewable energy production.
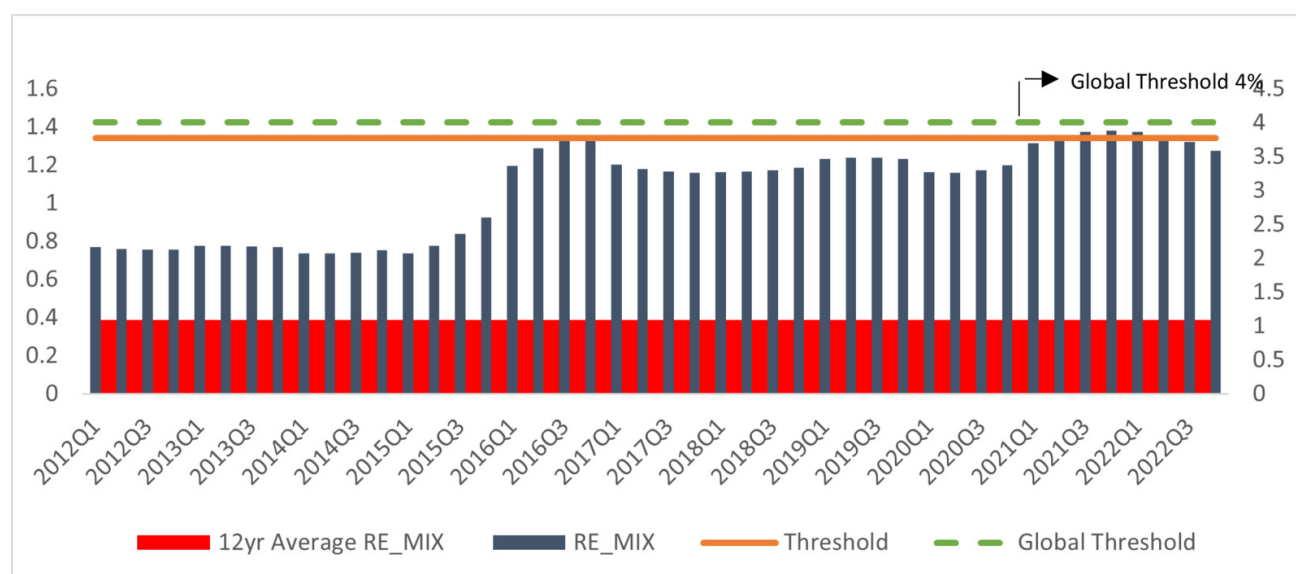

Figure 2. Renewable Energy Mix vs Optimal Threshold Level (2012Q1 – 2022Q4)

Source: World Bank Database, Author's Computation

IV. Conclusion and Policy Recommendations

This study aimed to determine the optimal energy mix for Nigeria's transition towards greener alternatives using a threshold regression analysis. The results indicated that Nigeria's energy mix has a threshold level of 1.34 per cent. At or below this threshold level, carbon emissions will increase; above the threshold level, carbon emissions will decrease.

Additionally, the results showed that growth in *GDP* per capita had a significant positive effect on carbon emissions due to increased economic activities and the burning of fossil fuels, particularly for industrial purposes.

To meet Nigeria's energy transition objectives, coordinated and focused policy initiatives from both monetary and fiscal authorities are needed. Fiscal authorities should intensify the deployment of green finance initiatives such as Green Bonds by the Debt Management Office. Fiscal authorities should also consider implementing carbon pricing mechanisms, such as carbon taxes or cap-and-trade systems to incentivize businesses to reduce their carbon footprints.

Simultaneously, monetary authorities, particularly the Central Bank of Nigeria, should prescribe sustainable banking guidelines which would require financial institutions to incorporate environmental and social considerations into their lending and investment decisions. This would promote funding for low-carbon businesses and reduce support for carbon-intensive industries.

The large-scale adoption of more green alternatives such as solar, wind, and hydro power across the country is not completely feasible due to high costs. A temporary but viable option would be substituting high-carbon emitting fuels, such as coal and crude oil with lower-carbon emitting or transition fuels, such as natural gas and Liquified Natural Gas (LNG). This can be done by strengthening the security of the country's pipeline infrastructure and establishing more natural gas processing plants.

References

Adegboyega, A., Omole, F. K., & Oyedepo, S. O. (2019). Barriers to renewable energy penetration in Nigeria. *Renewable and Sustainable Energy Reviews*, *110*, 395–408.

Alaganthiran, J. R., & Anaba, M. I. (2022). The effects of economic growth on carbon dioxide emissions in selected Sub-Saharan African (SSA) countries. *Heliyon*, *8*(11), e11193. https://doi.org/10.1016/j.heliyon.2022.e11193

Anyanwu, E. E., & Ajayi, O. O. (2018). A review of renewable energy development in Nigeria: Current status, future prospects, and policy recommendations. *Renewable and Sustainable Energy Reviews*, *94*, 38–53.

Bassongui, N., Nomo Alinga, D. N., & Mignamissi, D. (2021). Threshold effects of energy mix on environmental quality. *Journal of Bioeconomics*, *23*(2), 163–178. https://doi.org/10.1007/s10818-020-09305-5

Chen, Y., Wang, Z., & Zhong, Z. (2019). CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. *Renewable Energy*, *131*, 208–216. https://doi.org/10.1016/j.renene.2018.07.047

Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energy Strategy Reviews*, *24*, 38–50. https://doi.org/10.1016/j.esr.2019.01.006

IEA. (2021). *Renewables 2021*. International Energy Agency. https://www.iea.org/reports/renewables-2021

Luqman, M., Rayner, P. J., & Gurney, K. R. (2023). On the impact of urbanisation on CO2 emissions. *NPJ Urban Sustainability*, *3*(1), 6. https://doi.org/10.1038/s42949-023-00084-2

Maizland, L. (2022, November 4). *Global Climate Agreements: Successes and Failures*. Council on Foreign Relations. https://www.cfr.org/backgrounder/paris-global-climate-change-agreements

Metcalf, G. E. (2019). On the Economics of a Carbon Tax for the United States. *Brookings Papers on Economic Activity*, *2019*(1), 405–484. https://doi.org/10.1353/eca.2019.0005

Nwosu, O., & Anyanwu, O. E. (2021). Assessing the transition to renewable energy in Nigeria: A review of barriers and enabling factors. *Renewable and Sustainable Energy Reviews*, *135*, 110320.

Oyedepo, S. O., Adejumobi, I. A., & Oyedepo, O. S. (2020). Renewable energy potential and policies for sustainable energy development in Nigeria. *Journal of Cleaner Production*, *249*, 119263.

Saidur, R., Islam, M. R., Rahim, N. A., & Solangi, K. H. (2010). A review on global wind energy policy. *Renewable and Sustainable Energy Reviews*, *14*(7), 1744–1762. https://doi.org/10.1016/j.rser.2010.03.007

Saleem, H., Khan, M. B., Shabbir, M. S., Khan, G. Y., & Usman, M. (2022). Nexus between non-renewable energy production, CO2 emissions, and healthcare spending in OECD economies. *Environmental Science and Pollution Research*, *29*(31), 47286–47297. https://doi.org/10.1007/s11356-021-18131-9

Sikder, M., Wang, C., Yao, X., Huai, X., Wu, L., KwameYeboah, F., Wood, J., Zhao, Y., & Dou, X. (2022). The integrated impact of GDP growth, industrialization, energy use, and urbanization on CO2 emissions in developing countries: evidence from the panel ARDL approach. *Science of the Total Environment*, *837*, 155795. https://doi.org/10.1016/j.scitotenv.2022.155795

Stokes, L. C. (2013). The politics of renewable energy policies: The case of feed-in tariffs in Ontario, Canada. *Energy Policy*, *56*, 490–500. https://doi.org/10.1016/j.enpol.2013.01.009

Sun, W., & Huang, C. (2020). How does urbanization affect carbon emission efficiency? Evidence from China. *Journal of Cleaner Production*, *272*, 122828. https://doi.org/10.1016/j.jclepro.2020.122828

Tong, H. (1983). Threshold Models. In *Threshold Models in Non-linear Time Series Analysis* (Vol. 21, pp. 59–121). Springer New York. https://doi.org/10.1007/978-1-4684-7888-4_3

Appendix

Table A.1. Granger Causality Wald test

Dependent variable	Independent variables	CHI2	DF	PROB > CHI2
CO2	ALL	15.369*	6	0.018

Note: * Indicates significance at 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.
The granger causality test above indicates that GDP per capita, urban population growth, and energy mix granger cause carbon emissions