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# EXAMINATION OF THE INFLUENCE OF WOOD FUEL USE ON GREEN ECONOMIC GROWTH IN NIGERIA

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**Abstract** *The study investigates the influence of wood fuel consumption on green economic growth in Nigeria from 1990 to 2023 using the Autoregressive Distributed Lag (ARDL) approach. The bounds test confirms the existence of a long-run relationship among the variables. The long-run empirical results indicate that trade openness significantly promotes green growth at 1% level, whereas wood fuel consumption and environmental sustainability indicators do not exert statistically significant effects. This suggests that reliance on wood fuel does not contribute to the transition toward a green economy. In the short run, trade openness also contributes positively to green growth, reinforcing its role in supporting environmentally compatible economic activities. The error-correction term is negative and significant (-0.78), indicating that approximately 78% of deviations from long-run equilibrium are corrected each period. Robustness checks using FMOLS, DOLS, and CCR validate the long-run estimates. The study recommends expanding access to affordable energy alternatives and strengthening environmental governance frameworks by providing subsidies and tax relief for clean cooking technologies such as LPG, solar cookstoves, and improved biomass stoves to reduce household dependence on wood fuel.*

**Keywords** green growth, energy transition, wood fuel, sustainable development, energy use

## Introduction

The global environmental change issues, especially the rise in global temperatures and its associated adverse effects on human life, have increasingly attracted the attention of international discourse. The continuous increase in greenhouse gas emissions, deforestation, and unsustainable energy consumption practices have intensified discussions within global frameworks, including the United Nation`s Sustainable Development Agenda, as well as the Paris Agreement. These frameworks emphasise the need for economies to

transition to environmentally responsible growth models. As a result, green growth has gained prominence as a development approach that promotes economic advancement while ensuring environmental sustainability, efficient resource use, and social equity (Sohail et al., 2024).

Green economic growth involves expanding economic activities in a manner that preserves natural resources, improves resource efficiency, and promotes sustainable consumption and production (Razelan et al., 2024). It emphasises the need to balance ecological protection with economic growth through responsible and efficient use of both renewable and non-renewable resources to sustain a resilient, healthy, and clean environment. Green growth represents an economic strategy aimed at minimising environmental degradation while supporting long-term development. It acknowledges the interdependence between economic growth, environmental protection, and social sustainability. Therefore, achieving green economic growth is fundamental to maintaining sustainable development and improving the living standard for both present and future generations. Green growth strategies stress the transformation or change from fossil fuels to renewable and cleaner energy sources, an adjustment that reduces the effects of climate change and enhances environmental quality (Javed et al., 2024). It also aligns with the global agenda for sustainable development of clean and affordable energy, responsible consumption and production, as well as climate action (SDGs 7, 12, and 13) (Wei et al., 2023).

Nigeria is endowed with vast natural resources, diverse vegetation, and a wide range of energy sources, including hydro, oil and gas, coal, wind, and solar. If managed well, these resources can significantly alleviate the nation's energy challenges, particularly for domestic use. Solid fuels, especially wood fuel (firewood and charcoal), account for more than 80% of domestic energy needs, particularly in rural and some urban areas where access to modern, affordable, and reliable alternative energy sources is limited (Samaila et al., 2025; Maina et al., 2020). Similarly, according to a 2024 National Bureau of Statistics (NBS, 2024) survey, 67.8% of households in Nigeria use wood fuel for cooking, heating, and other small-scale processing activities; as such, it remains the primary source of energy for many households in the country. While reliance on this pattern of energy use in the country offers short-term economic benefits and support for livelihood activities, it comes with substantial environmental implications (Audu et al., 2023).

Consequently, the unsustainable harvesting of wood fuel contributes to deforestation, forest degradation, biodiversity loss, and depletion of natural vegetation cover (Abebaw, 2024). These environmental disturbances reduce the forests` capacity to act as carbon sinks, thereby increasing carbon dioxide emissions and exacerbating climate change. Additionally, the reduction of forest resources weakens ecosystem services such as soil fertility, water regulation, and climate stabilisation, all of which are essential for long-term economic productivity and human well-being. As such, wood fuel combustion in households

produces indoor air pollution with serious public health effects. Prolonged exposure to smoke from firewood and charcoal has been linked to respiratory infections, eye diseases, and increased mortality among women and children who spend more time cooking indoors (Abraham et al., 2022). These environmental implications suggest that persistent dependence on wood fuel may pose a significant challenge to efforts towards achieving green and resilient economic growth.

This study is therefore motivated by the widespread reliance on wood fuel in Nigeria due to its affordability and accessibility, despite its contributions to forest depletion and environmental sustainability. An understanding of how wood fuel consumption affects green economic growth is therefore important for developing policies that balance energy accessibility with environmental sustainability. In line with this motivation, the study aims to examine how wood fuel energy use influences green economic growth, while incorporating trade openness and environmental sustainability indicators as explanatory variables to reduce specification bias in the model.

Although some studies have looked into the link between wood fuel, biomass energy use, and the environment (see Samaila et al., 2025; Asefon, 2024; Audu, 2023; Maina et al., 2020; Sulaiman and Abdul-Rahim, 2020; and Sulaiman et al., 2017), much of the existing research focusses on broader issues such as environmental degradation, household energy consumption behaviour, and forest depletion rather than on green economic growth. Likewise, recent studies on green growth (Razelan, 2024; Sohail et al., 2024; Javed et al., 2024; Wei et al., 2023) have concentrated on other macroeconomic variables, while little or no attention is paid to wood fuel as a determinant. Consequently, empirical evidence on the role of wood fuel consumption in shaping green economic growth, particularly in developing economies, remains scarce. Hence, this study aims to fill this gap by examining the impact of wood fuel energy use on green economic growth in Nigeria using annual time-series data from 1990 to 2023 and the autoregressive distributive lag model as an estimation technique, thereby extending the green growth literature beyond conventional energy and environmental perspectives.

The following structure is remainder of the paper: apart from introduction, section two presents the review of relevant literature. Section three discusses the methodology, including data sources, model specification, and estimation technique. Section four presents and discusses the empirical results, while Section five concludes with policy recommendations.

## 2. Literature review

Green growth refers to an environmentally sustainable form of economic expansion that promotes social inclusiveness while minimising ecological degradation (Sohail et al., 2024). It is rooted in the idea that long-term economic progress depends on the efficient and responsible use of natural resources. Consequently, a growing body of research has examined the macroeconomic and

environmental determinants of green economic growth across global, regional, and national contexts.

### 2.1 Global and regional evidence on green growth determinants

Several empirical studies have highlighted the influence of trade, innovation, and renewable resources in enhancing green growth. Razelan (2024), using ARDL and dynamic ARDL techniques on data from 1990-2021 for Malaysia, found that green trade plays a significant impact in promoting green economic growth in both the short and long run. Similarly, Sohail et al. (2024) used CS-ARDL on data from 2000-2022 for 33 economies. They reported that bioenergy contributes positively to green growth in the long run, though its short-run effect is not significant. Moreover, forest trade was shown to enhance green growth in both horizons. In another study, Javed et al. (2024) used the CS-ARDL model on annual data from 1990 to 2019 to assess the influence of energy efficiency and green innovation among the top ten manufacturing economies. They found that green technology, energy efficiency, and human capital raise environmental performance, whereas trade openness and economic expansion exert negative environmental effects. In addition, Wei et al. (2023), using CS-ARDL on data from 1990 to 2018 across the top green-growth economies, concluded that renewable energy, green innovation, and green growth improve environmental quality, while green trade does not yield consistent benefits.

### 2.2 Biomass and wood fuel use in economic and environmental outcomes

Research focusing specifically on biomass and wood fuel reveals mixed outcomes depending on economic structure and technological efficiency. A study conducted between 1979 and 2017 in Sub-Saharan Africa by Sulaiman and Abdul-Rahim (2020) found that wood fuel consumption exerts a significant negative effect on economic growth in both the long and short run. Similarly, using the dynamic autoregressive distributed lag estimation method on annual data from 1982 to 2017 in China, Danish and Ulucak (2020) found a long-run negative link between biomass energy use and $CO_2$ emissions, while foreign direct investment increased emissions. This indicates that biomass energy can support environmental sustainability when combined with supportive policies.

Destek et al. (2021) utilised panel data for the U.S., China, Germany, India, and Brazil from 1970 to 2016 and continuously updated fully modified and continuously updated bias-corrected panel estimation techniques that control for cross-section dependence. They confirmed that biomass energy contributes to reducing carbon dioxide emissions, thus supporting environmental sustainability. In BRICS countries, Aydin (2019) employed the Augmented Mean Group (AMG) on data from 1992 to 2013. The study reported that in the long-term biomass energy consumption has a positive impact on growth of the economy in all countries except Brazil. Conversely, Sulaiman et al. (2017) applied the dynamic Generalised Method of Moment (GMM) estimation

technique on data from 2005-2013 for Sub-Saharan African nations; they found that wood fuel use exacerbates forest degradation. Additionally, Shahbaz et al. (2016) used the panel cointegration technique on annual data from 1991Q1-2015Q4 to examine BRICS countries; they reported that biomass energy promotes economic growth, while trade openness has both short- and long-run growth effects on economic growth.

### 2.3 Local evidence on wood fuel use in Nigeria

At the domestic level, studies have primarily focused on household consumption patterns and environmental consequences. Samaila et al. (2025) reported that rising scarcity of fuelwood in Michika, Adamawa State, has encouraged households to switch to charcoal as an alternative source. Asefon (2024) highlighted that wood fuel consumption contributes to deforestation, environmental pollution, and climate change. Similarly, Audu (2023) showed that in Yobe State, fuelwood collection serves as a major livelihood source, emphasising its economic relevance. Teru et al. (2022) reported the massive exploitation of trees in the Ganye area of Adamawa State has resulted in soil erosion, flooding, the disappearance of many tree species within their surroundings, the occurrence of drought and an increase in temperature at a threatening rate, and there has been serious. Maina et al. (2020) and Isah and Ahman (2020) found that household energy demand, driven by larger household sizes and low incomes, promotes greater dependence on wood fuel, thereby accelerating vegetation loss.

### 2.4 Gap in the literature

The reviewed studies provide valuable insights into the environmental and socio-economic implications of wood fuel use. However, most Nigerian studies focus primarily on environmental degradation, household behaviour, and forest depletion, rather than assessing how wood fuel consumption influences green economic growth at the national level. Additionally, existing empirical evidence does not clarify the long-run sustainability implications of continued reliance on wood fuel in Nigeria's economic system. This study fills this gap by empirically examining the influence of wood fuel usage on green growth in Nigeria; by adopting advanced time-series estimation techniques, the study provides new evidence on whether wood fuel consumption supports or undermines Nigeria's transition toward a green growth pathway.

The gaps identified in the literature strongly justify the focus on Nigeria. Although existing studies highlight the environmental and socio-economic implications of wood fuel use, they rarely examine how this form of energy consumption affects green economic growth, which is central to Nigeria's long-term sustainability agenda. Given that wood fuel accounts for a significant share of household energy use in Nigeria despite the country's abundant renewable and non-renewable energy resources there is a critical need to understand whether this dependence aligns with or undermines the nation's green growth aspirations. By concentrating on Nigeria, this study directly responds to the unresolved question of how continued reliance on wood fuel interacts

with national development goals, environmental commitments, and the transition toward a more sustainable economic pathway. This motivates the empirical investigation using advanced time-series techniques to evaluate Nigeria's unique energy-environment-growth dynamics.

## 3. Methodology

### 3.1 Model specification

The study adapted and modified a model recently specified by Razelan et al. (2024) in one of his works which explored the connection between green trade and green growth. As such, the equation is presented as follows:

$$GRG_t = F(WUFL_t, ESTB_t, TROPN_t) \quad (1)$$

Thus, the econometric specification of the model is presented in equation 2.

$$lnGRG_t = \partial_0 + \partial_1 lnWUFL_t + \partial_2 lnESTB_t + \partial_3 lnTROPN_t + u_t \quad (2)$$

Where: *ln* represents natural logarithm; $GRG$ denotes green growth which is the dependent variable; $WUFL$ indicates woof fuel; while $ESTB$ represents environmental sustainability; $TROPN$ represents trade openness are the explanatory variables; $\partial_0$ is the drift indicator of the model; while $u_t$ is the residual term envisaged to be distributed normally. We anticipate $\partial_2$ to be less than 0 and $\partial_1$ and $\partial_3$ to be greater than 0.

### 3.2 Data

The study uses secondary data covering the period 1990 to 2023, sourced from the World Bank`s World Development Indicators, the Nigerian Bureau of Statistics, and the Food and Agriculture Organisation of the United Nations. The dataset includes wood fuel use as the independent variable and the green growth as the dependent. Environmental sustainability and trade openness are included as a control variables to account for factors that may influence the relationship between energy use and economic performance. Specifically, environmental sustainability captures the broader ecological constraints that may affect green growth, while trade openness reflects the impact of international market integration on resource utilization and economic outcomes. The selected period is appropriate, as it captures long-term trends in energy use, environmental performance, and macroeconomic dynamics necessary for examining the influence of wood fuel in Nigeria's transition toward a green growth pathway.

***Variable definition, Proxy, and Sources***

Table 1 below lists the variables along with their proxies.

**Table 1: Variables and proxies**

| Variable | Proxy | Source |
|---|---|---|
| Wood fuel consumption | Ratio of wood fuel to total biomass | FOA, 2023 |
| Green growth | Share of renewable energy supply in total energy supply | WDI, NBS, 2023 |
| Environmental sustainability | Carbon emissions per capita | WDI, 2023 |
| Trade openness | percentage of trade relative to gross domestic product. | WDI, 2023 |

Source: author`s compilation (2025)

### *3.3 Analytical technique*

To investigate how the wood fuel use affects green growth. It is imperative to determine if the data are stable. Thus, the study first ran a stationarity test to make sure there are no unit roots in any of the variables as well as to overcome the problem of false regression. The study uses the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) unit root tests to observe the order of integration of the variables. After confirming the order of integration of the variables, the study employed the Autoregressive Distributed Lag (ARDL) technique as formulated by Pesaran et al. (2001) as the estimation approach for this study. The rationale for employing this method lies in its versatility, allowing for the estimation of the series of variables at various levels, be it in their level form, first differences, or a combination of both. Unlike other estimation techniques like Johansen cointegration and Engel-Granger methods that require integration of variables at the first difference, the ARDL method excludes the need for such testing. Moreover, the ARDL method is well-regarded for its robust characteristics and consistent outcomes, even when dealing with limited sample sizes. One of its advantages is the simultaneous estimation of both long-term and short-term models within the same framework.

To apply the ARDL approach, the comprehensive functional and econometric equation serves as the basis from which ARDL specifications can be derived. From equation 2, the ARDL specification is expressed in equation 3 in order to estimate the long-run link amid green growth, wood fuel, environmental sustainability, and trade openness in the study area.

$$\Delta GRG_t = \partial_{0j} + \sum_{i=1}^{n} \partial_{1j} \Delta GRG_{t-i} + \sum_{i=1}^{n} \partial_{\partial 2j} \Delta lnWUFL_{t-i} + \sum_{i=0}^{n} \partial_{3j} \Delta lnESTB_{t-i} + \sum_{i=0}^{n} \partial_{4j} \Delta TROPN_{t-i} + \tau_1 GRG_{t-1} + \tau_2 lnWUFL_{t-1} + \tau_3 lnESTB_{t-1} + \tau_4 TROPN_{t-1} + \mu \quad (3)$$

Where: Δ is first difference operator; $\pi_0$ is the intercept; $\pi_1$ is coefficient of the short run; $\tau_1$ is the coefficient of the long-run variables and $\mu$ is the error term.

The bounds testing which relies on the Wald test (F-statistics) is employed to test the null hypothesis of no cointegration between wood fuel and environmental sustainability variables in Nigeria against the alternative hypothesis signifying the existence of cointegration between wood fuel and environmental sustainability variables.

$$H_o: \tau_1 = \tau_2 = \tau_3 = \tau_4 = 0$$

$$H_1: \tau_1 \neq \tau_2 \neq \tau_3 \neq \tau_4 = 0$$

According to Pesaran et al. (2001) long-run cointegration of the variables is implied if the F-statistics value is greater than I (1). Additionally, the cointegration between the variables is absent if the F-statistics value is less than I (0). Finally, the results are questionable if the F-statistics value lies between I (0) and I (1).

The error correction method (ECM) of the study is expressed in equation 4

$$\Delta GRG_t = \partial_{0i} + \sum_{i=1}^{n} \partial_{1i} \Delta lnWUFL_{t-i} + \sum_{i=0}^{n} \partial_{2i} ln\Delta ESTB_{t-i} + \sum_{i=0}^{n} \partial_{3i} \Delta TRONP_{t-i} + \varphi ECT_{t-1} + \varepsilon_t \quad (4)$$

Where: $\Delta$ represents the first difference operator, $\partial$ represents the short-run coefficient, $\varphi$ represents the speed of adjustment, while ECT is the error correction term which ranges between 0 and 1, and most be negative and statistically significant and $\varepsilon_t$ is the error term.

## 4. Results

This research addresses a significant question of whether wood fuel usage has an influence on green growth in Nigeria.

### *4.1 Pre-estimation test*

The descriptive summary and correlation analysis of datasets used are displayed in Table 2. As indicated, the probability values computed for the Jarque-Bera distribution are higher than the conventional statistical significance levels, which signifies that all the variables were not normally distributed. Regarding the skewness of the distribution, all the variables were positively skewed. Also, the kurtosis statistics of the series showed that all the variables (WUFL, ESTB, and TROPN) were platykurtic, except GRG, which was found to be leptokurtic.

We estimated the dependent variable (green growth) and the explanatory variables (wood fuel, environmental sustainability, and trade openness) using Pearson's correlation coefficients so as to reduce the impacts of multicollinearity in the data set. For multicollinearity to occur, according to Tabachnick et al. (2007), the relationship between two explanatory variables must be more than 0.9. The estimated result in Table 2 revealed a negative correlation between WUFL and ESTB with GRG, whereas a positive correlation exists between TROPN and GRG. This makes them more relevant to

our estimation model. Additionally, the highest correlation coefficient of our explanatory variables is between GRG and TROPN (0.41), which is slightly below 0.9. Thus, multicollinearity cannot be considered as a significant threat to our regression analysis.

**Table 2: Descriptive Statistics and Correlation matrix**

| | GRG | WFUL | ESTB | TROPN |
|---|---|---|---|---|
| Mean | 358.6484 | 449499.4 | 0.687554 | 35.36008 |
| Median | 360.1836 | 440200.0 | 0.653919 | 34.24085 |
| Maximum | 1295.314 | 682466.0 | 0.910979 | 53.27796 |
| Minimum | -175.6308 | 270791.0 | 0.501456 | 16.35219 |
| Std. Dev. | 333.6118 | 130160.4 | 0.110600 | 9.482679 |
| Skewness | 0.529976 | 0.040026 | 0.306246 | 0.019658 |
| Kurtosis | 3.463806 | 1.546971 | 1.846128 | 2.297120 |
| Jarque-Bera | 1.896370 | 3.000079 | 2.417636 | 0.702079 |
| Probability | 0.387444 | 0.223121 | 0.298550 | 0.703956 |
| Sample | 34 | 34 | 34 | 34 |
| | GRG | WFUL | ESTB | TROPN |
| GRG | 1.000000 | | | |
| WFUL | -0.023274 | 1.000000 | | |
| ESTB | -0.038940 | -0.850640 | 1.000000 | |
| TROPN | 0.409345 | -0.276228 | 0.344880 | 1.000000 |

Source: author`s computation (2025)

***4.1.1 Stationarity test***

As indicated in Table 3, the result of the stationarity tests for the ADF reveals that lnWUFL and lnESTB have a unit root at levels but become stationary after taking their first difference. Similarly, GRG and TROPN were found to be stationary at levels. The results of the PP test also indicated that GRG and TROPN were stationary at levels. However, InWULF and InESTB have unit roots at the levels, but after first differencing, they become stationary. Hence, a mixed order of integration exists in both the ADF and the PP tests, and this implies that the conditions to apply the Autoregressive Distributive Lag Model (ARDL) are satisfied.

**Table 3: Results of the stationarity test**

| Variables | ADF Test | | PP Test | | Order of Integration |
|---|---|---|---|---|---|
| | Level | First Difference | Level | First Difference | |
| GRG | -3.7823*** (0.0071) | _ | -3.9683*** (0.0044) | _ | I(0) |
| lnWFUL | -1.3245 (0.6060) | -3.7604*** (0.0077) | -1.1227 (0.6950) | -3.7114*** (0.0085) | I(1) |
| InESTB | -1.2921 (0.6214) | -6.2833*** (0.0000) | -1.2377 (0.6461) | -6.4885*** (0.000) | I(1) |
| TROPN | -2.8535* (0.0619) | _ | -2.8450* (0.0630) | _ | I(0) |
| Critical values | -4.273277 | -4.394309 | -4.273277 | -4.284580 | |
| | -3.557759 | -3.612199 | -3.557759 | -3.562882 | |
| | -3.212361 | -3.243079 | -3.212361 | -3.215267 | |

Note: (***), (**), and (*) represent the significant level at (1%), (5%), and (10%) respectively.

Source: author`s computation (2025)

***4.1.2 Lag selection criteria***

The lag selection order is important, and it is done by the system automatically; this enhances robustness and the fitness of the model. Degrees of freedom will not be lost, and the model will be free from being trapped in autocorrelation. In addition, the smaller the lag, the better the model, and the larger the lag, the less fit the model (Akaike, 1974). The outcome of the lag order is shown in Table 4.

**Table 4*:* Lag order selection criteria**

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | -288.8074 | NA | 3530.108 | 19.52049 | 19.70732 | 19.58026 |
| 1 | -206.3599 | 137.4126* | 42.59362* | 15.09066* | 16.02479* | 15.38949* |
| 2 | -195.5786 | 15.09377 | 64.27824 | 15.43857 | 17.12001 | 15.97648 |
| 3 | -182.8670 | 14.40644 | 94.78143 | 15.65780 | 18.08654 | 16.43478 |
| 4 | -168.4105 | 12.52897 | 150.9053 | 15.76070 | 18.93675 | 16.77675 |

Note: * Indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level). FPE: Final prediction error, AIC: Akaike information criterion. SC: Schwarz information criterion. HQ: Hannan-Quinn information criterion.

Source: *author`s computation (2025)*

As indicated in Table 4, the Akaike information criteria, the Schwarz information criteria, and the Hannan-Quinn criteria proposed one (1) lag as an appropriate order for the cointegration. The study uses the Akaike information criterion (15.090), which is the lowest value compared to the respective Schwarz information criteria (16.024) and Hannan-Quinn criteria (15.389).

To explore the possibility of cointegration in the model, a bound cointegration test was employed, and the outcome is indicated in Table 5. The test results revealed that the computed F-statistic (5.37) is way above the upper and lower critical values at the 1% significance level. Therefore, the assumption that there is no cointegration among the series is rejected, meaning there is a cointegration association among the variables.

**4.2 Estimation test**

**4.2.1 ARDL bound cointegration result**

**Table 5: Results for ARDL Bound Test for Cointegration**

| **MODEL**<br>$F_{GRG}$ (GRG, lnESTB, InWFUL, TROPN) | Null Hypothesis: No long-run relationship | |
|---|---|---|
| K=4 | | |
| *F*-Statistics | 5.3713**** | |
| Significance | Critical Values Lower bound I(0) | Critical Values Upper bound I(1) |
| 10% | 2.37 | 3.2 |
| 5% | 2.79 | 3.67 |
| 2.5% | 3.15 | 4.08 |
| 1% | 3.65 | 4.66 |

Note: k shows the number of explanatory variables. (****), (***), (**), and (*) indicates the significant level at (1%), (5%), (2.5%), and (10%).

Source: *author's computation (2025)*

In light of the existence of cointegration among the variables in the model, the findings for the long- and short-run relationship among GRG, InWFUL, lnESTB, and TROPN are indicated in Table 6. The model was estimated by the automatic selection of a maximum lag length of 1. Using Akaike information criteria (AIC) in selecting the ideal lag order for the model and the specification settled on ARDL (1, 0, 0, 1).

### 4.2.2 ARDL baseline result

**Table 6: Results of ARDL long-and short-run**

| variables | Dependent variable is GRG: ARDL (1,0,0,1) selected based on AIC | | | |
|---|---|---|---|---|
| | Coefficient | Std error | t-statistics | Prob. |
| **Long run coefficients** | | | | |
| lnWFUL | 197.3098 | 397.7202 | 0.496102 | 0.6238 |
| lnESTB | -324.5181 | 744.1146 | -0.436113 | 0.6662 |
| TROPN | 25.14591*** | 7.436399 | 3.381463 | 0.0022 |
| C | -3251.924 | 4934.703 | -0.658991 | 0.5155 |
| **Short run coefficients** | | | | |
| D(TROPN) | 10.65991** | 5.131870 | 2.077197 | 0.0474 |
| CointEq(-1)* | -0.781970*** | 0.140820 | -5.552973 | 0.0000 |
| **Models Diagnostic Tests** | | | | |
| $R^2$ = 0.50 | | Adj $R^2$ = 0.48 | | D-W = 2.02 |
| Normality Tests | 9.3790 | Serial Correlation | 0.2354 | |
| (Jarque-Bera) | (0.009) | (Breusch-Godfrey) | (0.7371) | |
| Heteroscedasticity | 1.0074 | Ramsey RESET | 1.2787 | |
| (Breusch-Pagan-Godfrey) | (0.3933) | | (0.2685) | |
| ARCH | 0.5566 | | | |
| | (0.5416) | | | |

Note: (***), (**), and (*) represent the significant level at (1%), (5%), and (10%) respectively. Figures under diagnostic test are F-statistics and P-values.

Source: *author`s computation (2025)*

The coefficient of wood fuel consumption in the long term is positive and not significant in influencing green growth at any level. Even though not significant, it may be attributed to policy inertia. This however, is not similar to the work of Sulaiman and Abdul-Rahim (2020), who found a negative and statistically significant relationship between wood fuel consumption and economic growth. Similarly, the coefficient of environmental sustainability is negative in influencing green growth in both the short and long run; however, it is not statistically significant at any level. Although the findings conform with the apriori expectation, it is also similar to the findings of Oyebanji et al. (2017), who examined green growth and environmental sustainability in Nigeria.

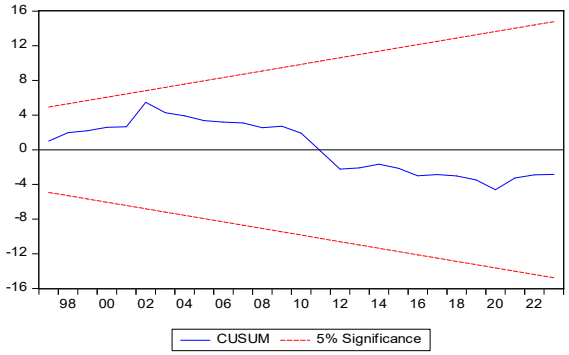
Additionally, the coefficient of trade openness has a positive and significant influence on green growth at the 5% level. This means a 1% rise in trade openness will lead to about a 25.15% increase in activities that contribute to green growth in the study area. However, this is not in tandem with the findings in the work of Sulaiman et al. (2017), who found a negative and statistically insignificant relationship to environment. While, in the short term, trade has a significant positive influence on green growth at a 5% level. The coefficient of trade openness (10.6599) implies that a 1% increase in trade will have about 10.66% influence on the green growth. This aligned with the apriori expectation.

Similarly, the negative and significant error-correction term confirms the presence of long-run equilibrium among the variables. The ECM displays the rate of long-term equilibrium adjustment following short-term shocks. The ECM coefficient of green growth is -0.7820 and statistically significant at the 1% level, demonstrating that any departure from the long-term equilibrium between wood fuel consumption and green growth can be corrected and recovered annually at 78%.

### 4.3 Post estimation test

As shown in Table 6, various diagnostic procedures were employed to find the model shortcomings. There are no problems of heteroscedasticity and serial correlation in model. However, the Jarque-Bera test indicated the model is not normally distributed. The model the model is correctly specified according to Ramsey RESET test. The goodness of fit of the model, as indicated by $R^2$ and adjusted $R^2$ of 48%, explains the proportion of variation in the green growth variable that is explained by wood fuel, environmental sustainability, and trade openness variables, which also indicated that the model fits the data well. In light of this, the study concludes that the parameters are reliable and consistent in their ability to account for variations in green growth during the study period.

To assess the stability of the estimated model, the cumulative sum of recursive residuals (CUSUM) and cumulative sum of recursive residuals of squares (CUSUM Squares) tests were used. As indicated in figures 1 and 2, the coefficients of CUSUM and CUSUM Square are clearly within the model's upper and lower critical bounds at the 5% level. Hence, the study concludes that the model is reasonably stable during the study period.



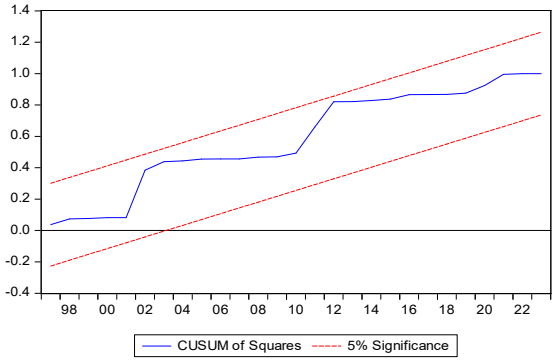



Figure 1: Plot of CUSUM Test

Figure 2: Plot of CUSUM of Squares Test

**4.4 Robust analysis**

To deal with robustness tests and the endogeneity problem in the long run coefficients of ARDL model. The study employed the Fully Modified OLS (FMOLS), the Dynamic OLS (DOLS), and the Canonical Cointegration Regression (CCR). According to Chandio et al. (2019), the FMOLS, DOLS, and CCR approaches are the best because they consider the mix order of integrating the appropriate components in the cointegrated method; they are also free from endogeneity issues and small sample size bias, and they are not hindered by the serial correlation problem.

**Table 7: Results for FMOLS, DOLS, CCR long-run relationship**

| Variables | FMOLS | | DOLS | | CCR | |
|---|---|---|---|---|---|---|
| | Coefficient | t-statistics | Coefficient | t-statistics | Coefficient | t-statistics |
| lnWFUL | -119.9296 | -0.299403 | 156.3287 | 0.177436 | -158.3769 | -0.372246 |
| lnESTB | -849.3703 | -1.127236 | -768.2031 | -0.447105 | -886.3079 | -1.046834 |
| TROPN | 22.65906 | 3.405797*** | 42.84009 | 3.146198*** | 23.60759 | 3.045657*** |
| C | 737.2821 | 0.148724 | -3449.586 | -0.319649 | 1198.841 | 0.229232 |
| $R^2$ | 0.27 | | 0.54 | | 0.27 | |
| Adj. $R^2$ | 0.20 | | 0.24 | | 0.19 | |

Note: (***), (**), and (*) indicates the significant level at (1%), (5%), and (10%).

Source: *author's Computation (2025)*

In the FMOLS model, only the coefficient of trade openness has a long-term statistically significant influence on green growth during the study period. This implies that a 1% increment in trade openness increases green growth by about 22.6%. This significant result supports the findings regarding ARDL long-term results indicated in Table 6. On the contrary, the coefficients of wood fuel and environmental sustainability are negatively related with green growth but not statistically significant at any level. This also aligns with the findings in the ARDL model. Similarly, in the DOLS model, the trade openness variable is positively associated with green growth at the 1% level of significance. This connotes that trade openness contributes to green growth during the study period. The long-term coefficients indicate that a 1% increment in trade openness increases green growth by 3.15% annually. However, the long-term coefficient of wood fuel (0.1774) and environmental sustainability (-0.4471) indicates a positive and negative link with green growth but is not statistically significant. Thus, these outputs are similar to the long-run ARDL results as presented in Table 6. Furtherance to this, using the

CCR estimation method, the results show a statistically insignificant association between wood fuel and environmental sustainability with green growth except for the trade openness, which is significant. Thus, in the CCR model, a 1% increase in trade openness uplifts an average of 3.05% of green growth. The significant coefficient of the CCR technique supports the long-run ARDL estimate presented in Table 5.

## 5. Discussion

The findings of this study provide insights into the nexus of wood fuel use, trade openness, and green growth in Nigeria. The long-run coefficient of wood fuel use (lnWFUL) is positive but statistically insignificant ($p > 0.05$), indicating that wood fuel consumption has negligible or no meaningful influence on green growth in the long run. This result contrasts with the expectation that heavy reliance on wood fuel would hinder sustainable growth due to its association with deforestation and environmental degradation. However, the insignificant outcome aligns with the evidence that in many low-income and rural contexts, wood fuel remains a basic livelihood necessity rather than a sector that directly drives macroeconomic growth (Samaila et al., 2025; Maina et al., 2020). This finding is consistent with studies that reported mixed effects of biomass depending on technological efficiency and economic structure. For instance, Sulaiman and Abdul-Rahim (2020) found that wood fuel use negatively affects economic growth in Sub-Saharan Africa, suggesting that its contribution to productivity is limited. Likewise, Sulaiman et al. (2017) showed that wood fuel dependence contributes to forest degradation without generating long-term economic benefits. The lack of a significant long-run effect in Nigeria therefore reflects a situation in which wood fuel use remains high, but its economic contribution is neither productive nor sustainable enough to drive green growth. In the short run, wood fuel use also has no significant influence on green growth, this supports the view that continued reliance on wood fuel is more of a coping strategy driven by energy poverty than a contributor to sustainable development (Asefon, 2024; Audu, 2023). This aligns with the local studies showing that household dependence on wood fuel is primarily associated with low income, absence of modern energy alternatives, and livelihood pressures rather than efficiency and innovation (Isah & Ahman, 2020; Teru et al., 2022).

Environmental sustainability (ESTB) shows a negative and statistically insignificant influence in both the long and short run; this is contrary to the findings of Oyebanji et al. (2017). This outcome may imply that the existing environmental sustainability efforts in Nigeria are not yet sufficiently integrated into the economic system to produce measurable improvements in green growth**.** In other words, the insignificant outcome suggests that environmental sustainability measures have not translated into tangible gains because they are not adequately influencing production processes, energy use, or land management practices.

Trade openness (TROPN) has a positive and significant influence on green growth in both the long run and short run. This result suggests that increased trade

integration supports green growth in Nigeria. This is consistent with Razelan (2024) and Sohail et al. (2024), who found that participation in green trade enhances access to cleaner technologies, promotes eco-friendly production, and strengthens environmental management practices in developing economies. However, it contrasts with Javed et al. (2024), who reported that trade openness negatively affects environmental performance in top manufacturing economies, where trade may increase carbon dioxide emissions through industrial expansion. The positive effect found in Nigeria likely reflects that Nigeria's trade exposure increasingly involves technology imports, renewable energy equipment, and policy-driven green transitions rather than purely emission-intensive industrial activity.

## 6. Conclusion

This study explores the influence of wood fuel usage on green growth in Nigeria, using annual data from 1990 to 2023. The study employed the ADF and PP tests to investigate the stationarity level of the variables, and the estimation reveals a mixed outcome. The study applied the Autoregressive Distributive Lag (ARDL) model for estimation of the model, and results show the existence of long- and short-run associations between wood fuel consumption and green growth in Nigeria. In the long run, only trade openness is found to be positively related to green growth. However, wood fuel and environmental sustainability were not significant in influencing green growth. Similarly, in the short run, an increase in trade openness has a positive influence on green growth. In addition, to verify the accuracy of the ARDL outcomes various tests such as Fully Modified OLS, Dynamic OLS, and Canonical Cointegration Regression (CCR) were estimated, and the estimated outcomes confirm that only trade has a long-term positive influence on green growth during the study period.

The study recommends expanding access to affordable energy alternatives and strengthening environmental governance frameworks by providing subsidies and tax relief for clean cooking technologies such as LPG, solar cookstoves, and improved biomass stoves to reduce household dependence on wood fuel. Strengthen forest management and enforcement mechanisms to regulate wood harvesting, promote reforestation, and improve coordination among environmental institutions. Trade policy should continue to encourage imports of clean energy technologies, renewable energy infrastructure, and climate-friendly innovations. Although the study provides important empirical insights, it is not free from limitations. The analysis depends solely on secondary data obtained from national and international statistical sources. The accuracy of the findings therefore depends on the reliability and completeness of these datasets, which may contain reporting gaps or measurement inconsistencies, especially wood fuel. The study employs country-level aggregate indicators, which may obscure substantial regional and household-level variations in wood fuel dependence and environmental conditions across Nigeria. Additionally, informal and unregistered wood fuel production and consumption common in rural and semi-urban communities are difficult to quantify and are likely

underreported, which may lead to an underestimation of the actual intensity of wood fuel use. As a suggestion for further studies on the influence of wood fuel usage on green growth, there is a need for a study on wood fuel consumption and environmental sustainability in the study area.

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