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THE ASYMMETRIC EFFECT OF HOUSEHOLD SOLID FUEL CONSUMPTION ON ENVIRONMENTAL QUALITY IN NIGERIA

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Abstract

This study seeks to examine the implications of Household Solid Fuel Consumption on Environmental Quality in Nigeria. The study ascertains the asymmetric roles of solid fuel consumption on Carbon emission (CO_2) using annual time series data covering the period 1971 to 2021. To conduct the empirical analysis, the study adopts the non-linear ARDL (NARDL) techniques. From the result of the estimated NARDL, it was established that environmental quality represented by carbon emissions (CO_2) responds positively and negatively to increases and decreases in solid fuel consumption with different magnitudes. The Wald test established the existence of long-run and short-run asymmetries in the relationship. The study therefore supports the need for government through the energy authorities to provide flexible platforms for environmentally friendly and efficient fuels to be used in place of solid fuels.

Keywords: Asymmetry, Household, Solid Fuel, Environment.

1. Introduction

Every advanced and emerging economy in the world is striving for an appropriate standard of sustainable development, but climate change and global warming, both prevalent and contentious environmental issues, pose an imminent threat to achieving this goal (Alege, Adediran & Ogundipe, 2021). Environmental quality is important because it provides basic needs such as safe water and air, fertile agricultural land for food production, and inputs of energy and materials for production (European Environment Agency [EEA], 2022). Energy consumption not only contributes to economic growth but also catalyzes sectorial growth in any country, particularly in household activities such as electrification, heating, cooking, transportation, and communication (Le & Nguyen, 2019; Mensah & Adu, 2015). The environment is an important route for human exposure to polluted air, noise, and hazardous chemicals (EEA, 2022). As a result, in any economy, human health and well-being are inextricably linked to the state of the environment.

Rising carbon dioxide (CO_2) emissions have raised concerns about the environmental and human health impacts of global energy consumption, particularly household energy consumption (Wang et al., 2019**)**. Due to the deterioration of environmental quality, the environment has recently come to the forefront of contemporary issues for both developed and developing countries (Kasman & Duma, 2015; Uddin, Salahuddin, Alam, & Gow, 2017). The reliance on fuel wood for domestic energy supply, for example, has accelerated deforestation, which is also triggering desertification in some parts of the country (Nasiru, 2015; Food and Agriculture Organization of the United Nations [FOA], 2015). The annual rate of deforestation is estimated to be around 3% per year, which equates to the loss of 410,000 hectares of forested land each year (FAO, 2015).

The Nigerian economy grew by an average of 4.92 percent from 1971 to 1980 before witnessing negative growth at an average of -0.18 percent from 1981 to 1990. However, the economy returned to a growth path from 1991 to 2000 at an average rate of 1.64 percent. Growth rates averaged 7.97 percent between 2001 and 2010, and 5.03 percent between 2011 and 2015. The oil glut led to a fall in the price of oil, culminating in a recession that saw the economy trend on a negative path at -1.61 percent in 2016 but return to a growth trajectory in 2021 at 3.64 percent. But despite this relative growth witnessed in some years, there have been increasing concerns about shortages in the energy supply, rises in energy use, and climate change in Nigeria (Ochada & Ayadi, 2020). Energy consumption is essentially viewed as the impetus behind any economic activity, including industrial production (Zhixin & Xin, 2011). As a result, there has been a shift to alternative energy sources and an increase in emissions (Akpan & Akpan, 2012; Onakoya, Onakoya, Jimi-Salami, & Odedairo, 2013; Dinh & Shih-Mo, 2015; Eregha & Mesagan, 2017). Household energy consumption, among other sources of energy, facilitates the day-to-day activities of human lives. This is especially true for some solid fuels, which have been linked to indoor pollution and dangerous levels of toxic emissions (Viegi et al., 2004; Staton & Harding, 2011).

The rural-urban drift, rising population, and increasing living standards have led to increased household energy consumption in Nigeria (Oyedepo, 2014; Shaaban & Petinrin, 2014). These household energy consumptions, which result in greenhouse gas emissions, pose a significant threat to the rise in global warming and climate change (Akpan & Akpan, 2012; Mohammed et al., 2012). Specifically, the household sector alone contributes to about 59% of the world's CO_2 emissions; however, in Nigeria, solid biomass fuels (for cooking and space heating) 1contribute to about 25% of the global emissions of CO_2 and about 50% of the anthropogenic emissions of black carbon (Maina, Kyari, & Jimme, 2020). Similar findings reveal that the household sector accounts for about 78% of the country's total energy consumption (Oseni, 2012), which is mostly dominated by fossil fuels and traditional solid biomass, and is often regarded as a major contributor to escalating CO_2 emissions, environmental pollution, and respiratory diseases in humans (Chafe et al., 2014; Mohammed et al., 2017*)*. Thus, the high concentrations of greenhouse gases in the atmosphere released through energy consumption cause environmental degradation (Lin & Raza, 2019).

The activities of humans involving a high use of energy pose threats to the environment and cause poor health, which can lead to reduced life expectancy and high rates of mortality (Afolayan & Aderemi, 2019). Could this challenge be traced to inadequate environmentally friendly energy sources such as solar energy and hydropower, which some individuals cannot afford due to low income resulting from poor economic performance in Nigeria? Literature has identified major drivers such as income, gender, lack of information on alternative energy systems, and cooking practices on the choice of household energy usage (IEA, 2006; Wuyuan et al., 2008; Schlag & Zuzarte, 2008). Deaths in Africa from outdoor air pollution have increased from 164,000 in 1990 to 258,000 in 2017—a growth of nearly 60% (Unicef, 2019). WHO (2015) earlier estimated 79,000 deaths per year in Nigeria from indoor air pollution, mainly caused by biomass burning. A growing body of evidence suggests that it also affects socially disadvantaged and vulnerable population groups (EEA, 2022). This is consistent with the earlier finding revealing that nearly 1800 people die every day in developing cities as a result of poor environmental quality (WHO, 2004; Oguntoke & Adeyemi, 2017; Matthew et al., 2018). This is on top of an average of 47.59 years in Nigeria between 1971 and 2021 (World Bank, 2021). This is even more pronounced in developing countries since poorer people are more likely to live in degraded environments. Poor health outcomes, such as low life expectancy and a subsequent high mortality rate have also been linked to poor environmental quality and environmental degradation caused by the use of dirty energy sources (Balan, 2016;

Matthew et al., 2018; Matthew et al., 2019; Mesagan & Ekundayo, 2015; Sharma, 2017).

Nigeria is a member of several multilateral policy agreements on environmental protection. For instance, during the Kyoto Protocol in 2004, Nigeria became a member on climate change policies (Vermeulen et al., 2012), and in December 2017, it also became a signatory to the Paris Agreement on CO_2 emission reduction targets and the Intergovernmental Panel on Climate Change (IPCC). Back home, there is a revised 2016 national policy on the environment targeted towards environmental protection and the conservation of natural resources. Fewer studies (Ubuoh & Nwajiobi, 2018; Maina, Kyari & Jimme, 2020; Lin & Raza, 2019; Afolayan & Aderemi, 2019; Ochada & Ayadi, 2020; Ibrahim & Cudjoe, 2021) have paid attention to this area of research in Nigeria. Nigeria is a developing economy, and thus there is a constant need to conduct this kind of study to ascertain the current situation and guide future policy formulation. Therefore, this study looks at the implication of household solid fuel energy consumption (disaggregated into soil fuel, fossil fuel, and gaseous fuel consumption) on environmental quality (proxied by CO_2 emissions). This paper is therefore divided into five sections. Section one: Introduction, Section two: Literature Review, Section three: Theoretical Framework and Materials and Methods, Section 4: Results and Discussion, and Section five: Conclusions and Policy Remarks

2. Literature Review

The concept of household energy is commonly referred to as the amount of energy consumed in homes to meet household needs (Kadiri & Alabi, 2014; McGranahan & Kaijser, 1993). Based on usage, household energy includes fuel wood, dung, agricultural residues, charcoal, kerosene, Liquefied Petroleum Gas (LPG), and electricity. Emagbetere, et al (2016) identified two classes of energy utilized in households' solid fuels and nonsolid fuels. The solid fuels include fossil fuels (coal and peat) and biomass (wood, dung, and agricultural residues), while the non-solid fuels consist of kerosene, liquefied natural gas, and electricity. Consequently, the household sector is therefore seen as one of the most important energy-consuming sectors in the world (Wang, et al., 2011). Environmental quality is a broad term that encompasses a wide range of features such as air and water quality or pollution, noise, access to open space, and the exterior appearance of buildings, as well as the potential effects that such features may have on physical and mental health (due to human activities) (European Environment Agency, 2022). This study adopts the definition of solid fuel by Emagbetere, et al (2016) where solid fuel is defined as fuels that include fossil fuels (coal and peat) and biomass (wood, dung, and agricultural residues).

The theoretical framework of this study is centered on the environmental Kuznets hypothesis. According to the Environmental Kuznets curve hypothesis, there is an inverted U-shape relationship between degradation of the environment (carbon emissions) and per capita income, with contamination or other forms of degradation increasing in the initial phases of economic development and decreasing in the later stages. According to Kuznets (1955), the changing relationship between per capita income and income inequality is an inverted U-shaped curve. As per capita income rises, so does income inequality, which begins to fall after a tipping point (TP).

In a developing economy where there is an increase in energy consumption, it is expected that there will be an increase in economic growth but this increase has a downward effect on the environment. The more energy is used, the more economic activities, hence growth but this affects the environment negatively, which is the cause of the inverted U shape in the Environmental Kuznet curve hypotheses. Solid fuel usage in Nigeria by households contributes to household economic activities but there is a downward trend in the environment as the spillage in the use of household solid fuels affects the environment, this is why the environmental Kuznet curve hypothesis is the best theory for this study.

Empirically, there is a significant number of studies on this subject matter owing to the rising concern about global warming and climate change that is at the forefront of the world. As much as energy is being consumed by the industrial sector, the residential sector also consumes energy, literature revealed that about 80 percent of total energy consumed annually is consumed by the household sector and derived from solid biomass fuels utilized for various domestic activities (Mohammed et al., 2017).

Somoye, Ozdeser, and Seraj (2022) used a non-linear autoregressive distributed lag (NARDL) model to examine the effect of energy from renewable sources consumption (RNEW) on economic growth (RGDP) in Nigeria from 1990Q1 to 2019Q4. The bound test result indicates the variables' cointegration. Further results show that a positive RNEW shock reduces RGDP in the long run, whereas a negative shock increases RGDP. In the short run, a positive RNEW shock increases RGDP, while a negative shock decreases RGDP, though the difference is not significant. Because of the nature and source of renewable energy used in Nigeria, a positive shock in RNEW hurts RGDP.

Ibrahim and Cudjoe (2021) used the Vector Error Correction Model (VECM) to examine the environmental impact of Nigerian energy consumption from 1990 to 2018. The findings show that charcoal usage has a long-run tendency to reduce CO_2 emissions, whereas fuel wood consumption has a long-run potential to increase CO_2 emissions. Furthermore, the use of gas oil, and hydroelectric power has the potential to reduce CO_2 emissions, whereas natural gas and fuel oil consumption have a negative impact on CO_2 emissions.

Musa and Maijama'a (2020) investigated the impact of economic growth and energy consumption on environmental pollution in Nigeria from 1981 to 2014, employing Augmented Dickey-Fuller (ADF) and Philip Perron (PP) unit root tests, as well as the Autoregressive Distributed Lag (ARDL) Model. The results revealed that all variables were stationary at the first difference and cointegrated, whereas the long-run results revealed that economic growth and energy consumption have significant positive effects on environmental pollution, implying that rising economic activity and energy consumption are accountable for the rising amount of environmental pollution, whereas crude oil price has a negative and significant influence on environmental pollution, i.e. All of the short-run outcomes support their long-run counterparts.

From 1970 to 2017, Ochada and Ayadi (2020) investigated the relationship between energy consumption, air pollution, and economic growth in Nigeria. Empirical findings show that the shock of coal energy consumption to GDP per capita showed dynamic impulse response at constant positive response within the VAR equation systems. In the structural VAR equations, GDP per capita shocks to electricity consumption show a positive response in both the short and long run.

Maina, Kyari, and Jimme (2020) examined the environmental impact of household fuel expenditure in Nigeria. According to the Ordinary Least Squares (OLS) results, households spend a larger portion of their income on dirty fuels. Urban households, on the other hand, were found to emit more CO_2 than rural households. The Kuznet hypothesis has also been demonstrated to apply to Nigerian households.

Adetayo, Adeyinka, and Agbabiaka (2020) investigated domestic energy usage and its health implications among residents of Ondo State's Ese-Odo and Okitipupa Local Government Areas (LGA). Multiple regression analysis results show that environmental and socioeconomic factors influenced residents' choice of domestic energy type. The study also found that the most common self-reported illnesses were burns, blindness, stroke, cataracts, and pulmonary diseases. However, there is a relatively weak correlation between domestic energy consumption and ill-health among residents of a few LGAs in Ondo State.

Pokubo and Al-Habaibeh (2019) used descriptive statistics to investigate the current energy consumption mix of household energy use and its likely effects on the environment and health of Nigerians. According to empirical findings, the primary household energy sources in Nigeria are electricity, firewood, charcoal, and liquefied petroleum gas. As a result, the study concludes that the most common alternative energy use is fossil fuel-based energy and solid fuels for energy generation and consumption. Afolayan and Aderemi (2019) use Dynamic Ordinary Least Squares (DOLS) and Granger causality to investigate the relationship between environmental and health effects in Nigeria from 1980 to 2016. The findings show that CO2 emissions hurt mortality rates, whereas electric power and fossil fuel consumption have a positive effect on mortality rates. Granger causality findings show that changes in mortality rates are caused by changes in life expectancy, while changes in electric power consumption are caused by changes in fossil fuel consumption.

Mesagan and Nwachukwu (2018) examined urbanization, per capita income, environmental degradation, energy consumption, trade intensity, and capital investment using the ARDL bounds testing approach. According to ARDL findings, income and energy consumption are responsible for environmental degradation. There is also bidirectional causality between energy consumption and environmental degradation.

Wang et al. (2018) used a vector error-correction model to find evidence of varying Granger causality relationships between energy consumption, economic growth, CO2 emissions, and urbanization across income-based subpanels. Ubuoh and Nwajiobi (2018) investigated the effects of various household cooking energy sources (firewood stoves, kerosene stoves, charcoal stoves, electricity stoves, and gas cookers) on indoor air quality in Imo, South Eastern Nigeria. The study employs ANOVA, and the results show that household energy accounts for environmental factors, with fuelwood being the most significant contributor compared to charcoal and kerosene. The study also found that using a gas cooker or an electric stove is less harmful to the environment. Matthew et al. (2018) used the ARDL approach to establish a negative correlation between greenhouse gas emissions and established a negative correlation between greenhouse gas (GHG) emissions and health outcomes in Nigeria. Specifically, the evidence reveals that an increase in GHG emissions reduces life expectancy at birth in Nigeria.

Gujba, Mulugetta, and Azapagic (2015) investigated the life cycle environmental impacts and costs of the Nigerian household cooking sector from 2003 to 2030. Using content analysis and exploratory data analysis, researchers discovered that if nothing is done, the environmental impacts and costs would increase by up to four times, owing to high fuel wood consumption.

Sinha (2014) investigated the link between environmental degradation and mortality rates in India from 1971 to 2010. The findings indicate a bidirectional causal relationship between infant mortality rate and CO2 emission growth, as well as growth in gross capital formation and child mortality rate. The study of Balan (2016) for the period 1995 to 2013 in 25 EU countries, however, shows that the energy consumption source of CO_2 matters in the determination of the relationship between environmental quality and health outcomes.

Various studies have based energy consumption on environmental kusnet curve considering the positive and negative implications of its consumption but these literature have lacked in appropriating the convenient methodology in their analysis, for example,Ibrahim and Cudjoe (2021) employed Vector Error Correction Model (VECM) to analyse environmental impact of energy consumption in Nigeria from 1990-2018, Musa and Maijama'a (2020) investigated the influence of economic growth and energy consumption on environmental pollution in Nigeria for over 1981-2014 periods and utilized Augmented Dickey Fuller (ADF) and Philip Perron (PP) unit root tests together with Autoregressive Distributed Lag (ARDL) Model, Ochada and Ayadi (2020) used structural VAR to examine the association among energy consumption, air pollution and economic growth in Nigeria from 1970-2017, other studies employed OLS, Granger causality and other methodologies but these methods do no adequately bring out the negative and positive features embedded in energy consumption, this current study therefore attempted to close this gap by utilizing a better and encompassing Nonlinear Autoregressive Distributed lag Model which most of the studies reviewed failed to use.

3. Methodology

Asymmetric ARDL (NARDL) Model

The study's objective is to determine the relationship between solid fuel consumption and environmental quality using an asymmetric (non-linear ARDL) approach to determine short-run and long-run asymmetric relationships. The solid fuel consumption variable is decomposed into positive and negative changes such that in the analysis, the study captured probable asymmetric behavior of solid fuel consumption on environmental quality. This approach follows the NARDL of Shin et al. (2014) which appears less computationally intensive compared to other asymmetric models and does not require identical order of integration {i.e. I(1)} for all the series in the model. The NARDL is given as:

$$\Delta CO2_t = \alpha_0 + \alpha_1 CO2_{t-1} + \alpha_2 SFC\_POS_{t-1} + \alpha_3 SFC\_NEG_{t-1} + \alpha_4 X_{t-1} + \sum_{i=1}^{N_1} \lambda_1 \Delta CO2_{t-i} + \sum_{j=0}^{N_2} (\lambda^+ \Delta SFC\_POS_{t-j} + \lambda^- \Delta SFC\_NEG_{t-j}) + \sum_{j=0}^{N_3} \lambda_3 \Delta X_{t-j} + \varepsilon_t \ldots\ldots (1)$$

In equation (1), the solid fuel consumption variable () has been decomposed into positive and negative changes respectively. These decomposed solid fuel consumptions are defined theoretically as:

$$SFC\_POS_t = \sum_{j=1}^{t} \Delta SFC\_POS_j = \sum_{j=1}^{t} \max(\Delta SFC_{j,} 0) \ldots\ldots\ldots\ldots (2)$$

$$SFC\_NEG_t = \sum_{j=1}^{t} \Delta SFC\_NEG_j = \sum_{j=1}^{t} \min(\Delta SFC_{j,} 0) \ldots\ldots\ldots\ldots\ldots (3)$$

Then respecify the equation (1) to include an error correction term thus:

$$\Delta CO2_t = \tau \xi_{t-1} + \sum_{i=1}^{N_1} \lambda_1 \Delta CO2_{t-i} + \sum_{j=0}^{N_2} (\lambda^+ \Delta SFC\_POS^+_{t-j} + \lambda^- \Delta SFC\_NEG^-_{t-j}) + \sum_{j=0}^{N_3} \lambda_3 \Delta X_{t-j} + \varepsilon_t \ldots\ldots (4)$$

It is important to note that just like the linear ARDL, the long run is estimated only if there is the presence of cointegration. Thus, pre-testing for cointegration is necessary even under NARDL and this involves the Bounds testing that is F-distributed. In addition, we also employ the Wald test for testing restrictions to ascertain whether the asymmetries matter. For the Wald test, the null hypothesis of no asymmetries- $H_0 : \alpha_2 = \alpha_3$ (for the long run) and $H_0 : \sum_{j=0}^{N1} \lambda_j^+ = \sum_{j=0}^{N2} \lambda_j^-$ (for the short run) is tested against the alternative presence of asymmetries - $H_1 : \alpha_2 \neq \alpha_3$ for the long run and the short run.

3.2 Data

This study used secondary data sourced from the Central Bank of Nigeria and the World Bank's database for the variables in the model. The data spans 1971 to 2021 using Carbon dioxide (CO_2) as the dependent variable. Solid fuel consumption as an independent variable of interest. Other variables that support the modeling of environmental quality and solid fuel consumption nexus include; Gross domestic product (GDP), Gacious Fuel Consumption GFC, Rural Population (RPOP), and Liquid Fuel Consumption (LFC).

4. Results and Discussion

Unit Root Results

In line with the typical procedure for modeling with time series, the study subjects each of the series in the model to unit root testing. For robustness purposes, the study presents the Augmented DickeyFuller (ADF) test in Table 1. Given the requirement of the bounds testing procedure that I(2) variables are not involved, In the test we include both constant and trend terms and employ the SIC for optimal lag order. The ADF agrees that none of the variables are I(2) which made it possible to proceed with the chosen model.

Table 1: Summary of Stationarity Test Results

Variables	**Augmented Dickey-Fuller**			
	Level	1st Diff	Decision	Order of Integration
CO_2	-2.573422	-3.3.686736***	Stationary at level and first difference	I(1)
SFC	-2.390944	-4.465809***		I(1)
LFC	-1.760627	-4.860897***		I(1)
GFC	-1.332793	-4.776703***		I(1)
GDP	-3.390944**	-5.465809***		I(0)
RPOP	-3.760627***	-7.860897***		I(0)

*Notes: ***, **, and * denote 1%, 5%, and 10% significance levels respectively.*

Source: *Extract from E-view 10 output, 2022*

The result in Table 1 reveals that GDP and RPOP achieve stationarity at level [that is I(0)] while the series of CO_2, SFC, and GFC exhibit non-stationarity at level [that is, I(0)]. To make the time series data stationary for all variables in the model, the Unit Root Test was performed at the first difference and the results revealed that the series of CO_2, SFC, LFC, and GFC became stationary at the first difference [that is, I (1)]. At this point, the variables in the model are ready for bound cointegration tests and this is presented in Table 2.

Table 2: Bounds Test for Non-Linear ARDL (NARDL)

Panel B		
Model: NARDL		
F(CO2/SFC(NEG), SFC(POS), GFC, LFC, GDP, RPOP		
Critical value	*Lower Bound*	*Upper Bound*
1%	3.6	4.9
5%	2.87	4
10%	2.53	3.59
F-Statistics	6.42877	
Critical values from Narayan (2005)		

Source: *Extract from E-view 11 Output, January 2023*

Table 2 shows the F-statistics of 6.42877 for non-linear ARDL. This implies that the F-statistics calculated from the nonlinear ARDL models are greater than both the lower and upper-bound critical values at a 1% level of significance. This indicates an asymmetric long-run relationship between sustainable environmental quality (CO_2) and the explanatory variables. Hence, the long-run relationship, therefore, can take nonlinear forms. Given these diagnostics, the choice of nonlinear ARDL is correct and its outcomes can be depended upon to inform policy decisions. Having demonstrated the existence of correlation with the variables considered in the models, long-run dynamics can be evaluated, after ascertaining the appropriate lag.

Figure 1 Lag Selection

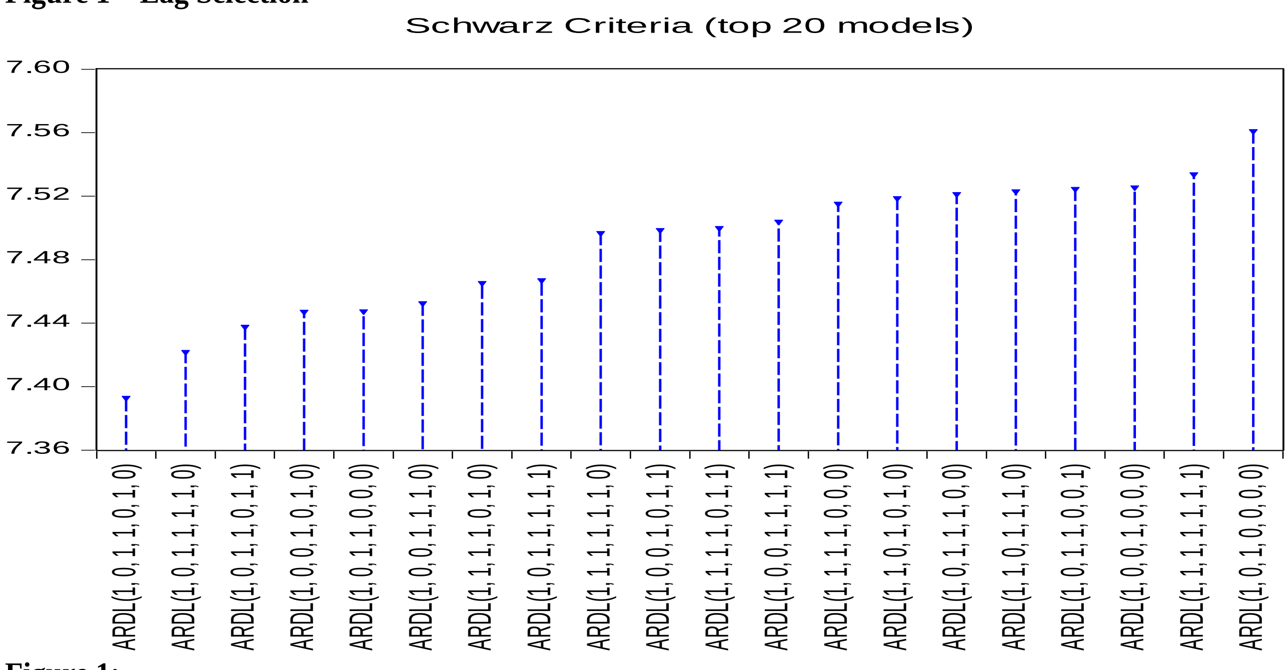

Figure 1:

The variables in the model, having been subjected to the lag selection criteria test, are presented in Figure 1. The choice of lag selection criterion depends on whether the study is for forecasting or impact analysis. If the study is for forecasting, the suitable criterion is the Akaike information while impact analysis goes with the Schwarz information criterion. Thus, this study is for impact analysis, the Schwarz information criterion is chosen for NARDL (at lag of 1, 0, 1, 1, 0, 1, 0).

Table 3.Estimated Long-run and Short-run Coefficients of Non-linear ARDL Model

NARDL Model		
Variable	Coefficient	p-value
Panel A	**Long-Run Estimates**	
SFC_POS	158.4387	0.0011
SFC_NEG	-1.447765	0.8583
GFC	-2.020619	0.0503
LFC	1.005410	0.0107
GDP	-5.485667	0.2529
RPOP	17.61713	0.1528
Panel B	**Short-Run Estimates**	
SFC_POS	77.86719	0.0012
SFC_NEG	-0.711527	0.8562
GFC	-0.993065	0.0077
LFC	0.494124	0.0014
GDP	-2.696018	0.2454
RPOP	8.658215	0.1440
C	88.04847	0.0074
CointEq(-1)*	-0.491466	0.0000

Extract from E-view 11 Output, January 2023

Table 3 holds the estimates of the long-run (Panel A) and short-run (Panel B) coefficients of the model to ascertain the asymmetric impact of Solid fuel consumption (SFC) on CO_2. From the result of the estimation, there is an asymmetric long-run relationship between Solid fuel consumption (SFC) and CO_2 in Nigeria. From the NARDL coefficients in Table 3 (Panel A), SFC_POS and SFC_NEG changes have a negative and positive relationship with CO_2 in the long run, however, only the SFC_POS exhibits significant impact in the long run. Implying that a unit increase in SFC in the long run would lead to a 158.4387 unit increase in CO_2 in Nigeria while a unit decrease in SFC in the long run will lead to a decrease in CO_2 by 1.447765 units in the long run. This finding confirms the presence of asymmetry, with the decrease and increase in solid fuel consumption having significantly different effects on CO_2 in Nigeria.

In the short run presented in Table 3 (Panel B), the episodes of positive and negative SFC changes are in the long run of which SFC_POS exhibits significant impact. A unit positive change in SFC in the short run leads to a 77.86719 unit increase in CO_2. Also, a unit negative change in SFC causes CO_2 to decrease by just 0.711527 units.

Table 4: Wald Test for NARDL

F-statistic	**Value**	**Df**	**Probability**
F-statistic	12.65358	(5, 38)	0.0000
Chi-square	63.26788	5	0.0000

Extract from E-view 11 Output

Table 4 represents the long-run and short-run asymmetries (Wald Test) results. The probability values of the F-statistics are significant. Hence, it rejects the null hypothesis SFC_POS=SFC_NEG=0 for the long run as well as the short run. Hence proof of the existence of long-run and short-run asymmetries in the relationship.

Table 5: Diagnostic Test

NARDL		
LM Test	*F-statistic*	*Prob.*
Coefficients	0.685742	0.5102
Heteroskedasticity Test ARCH		
Coefficients	0.491300	0.8969

Extract from E-view 11 Output

The F-statistics for serial correlation results are not significant as the probability is above the 5 percent level of significance, indicating no serial correlation. Also, the test for heteroscedasticity shows there is a variance in constant (homoscedasticity) given the probability value is greater than five percent thus, implying the absence of heteroscedasticity.

5. Conclusion and Recommendations

This study investigated the asymmetric implication of solid fuel consumption on environmental quality in Nigeria using annual time series data covering the period 1971 to 2021. First, the study used the nonlinear ARDL (NARDL) model recently which allows for the regressors to be decomposed into positive and negative partial sum processes so that the responses of the dependent variable to increases and decreases in the regressors can be modeled coherently. This study therefore provides policy insights into the role of energy as a key driver of environmental sustainability. From the result of the estimated NARDL, it was established that environmental quality proxied by carbon emission (CO_2) responds positively and negatively to increases and decreases in solid fuel consumption with different magnitudes. The Wald test established the existence of long-run and short-run asymmetries in the relationship. The study, therefore supports the need for government through the energy authorities to provide flexible platforms for environmentally friendly and efficient fuels to be used in place of solid fuels.

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