POLAC ECONOMICS REVIEW (PER)
DEPARTMENT OF ECONOMICS AND MANAGEMENT SCIENCE
NIGERIA POLICE ACADEMY, WUDIL-KANO

# IMPLICATIONS OF HOUSEHOLD SOLID FUEL CONSUMPTION ON ENVIRONMENTAL QUALITY IN NIGERIA

**Idakwoji Ojochogwu Blessing** Department of Economics, Kogi State University, Anyigba

**Bernard Tony** Department of Economics, Air force Institute of Technology, Kaduna

**Saheed Zakaree** Department of Economics, Nigerian Defence Academy, Kaduna

## Abstract

*This study examines the implication of household energy on environmental quality in Nigeria* Spanning the *period 1971-2021. Data for the analysis were sourced from World Bank's database while Autoregressive Distributed Lag (ARDL) approach was employed for the analysis. The study is hinged on environmental Kuznets hypothesis. The dependent variables include carbond dioxide emission proxied for environmental quality. The explanatory variables includes* solid fuel consumption *(% of total energy) (SFC) proxied for household energy while complementary vairables includes; fossil fuel consumption (FFC) (% of total energy), gaseous fuel consumption (GFC) (% of total energy), gross domestic product per capita (GDPPC) and rate of urbanization (UBN). The bound test result reveals that there is existence of long run relationship among the variables captured in the model. The finding reveals that household energy consumption proxied by solid fuel consumption account for an increase in carbon dioxide emission (worsening environmental quality) both in the long-run and short-run. Based on these outcomes, the study therefore recommends the need for Nigerian government to embark on serious sensitization on the need for the adoption of environmentally friendly energy for households use. The government in collaboration with relevant stakeholders need to provide household cooking apparatus without health implication at a subsidize rate.*

**Keywords:** Household, Solid Fuel, Environmental Quality, Carbon Emission, ARDL

## 1. Introduction

The task ahead of every developed and developing economy of the world reach a certain level of sustainable development, but climate change and global warming as common and controversial environmental issue pose a serious threat to achieving this milestone (Alege, Adediran & Ogundipe, 20216). Environmental quality matters because quality natural environments provide basic needs, in terms of clean air and water, fertile land for food production, and energy and material inputs for production (European Environment Agency [EEA], 2022). Energy consumption contributes not only to economic growth but acts as a propeller for sectoral development in any country especially household activities including electrification, heating, cooking, transportation and communication (***Le & Nguyen, 2019; Mensah & Adu, 2015)***. Environment represents an important pathway for human exposure to polluted air, noise and hazardous chemicals (EEA, 2022). Therefore, human health and well-being are intimately linked to the state of the environment of any economies.

The rising carbon dioxide (CO2) emission has raised concern on the impacts of global energy consumption especially household energy consumption on the environment and human health (***Wang, et al., 2019)***. In recent time, the environment has come to the forefront of contemporary issues for both developed and developing countries since the deterioration of environmental quality (Kasman & Duma, 2015; Uddin, Salahuddin, Alam, & Gow, 2017). For instance, the reliance on fuel wood for the domestic energy supply has exacerbated deforestation, which is also contributing to desertification in some parts of the country (Nasiru, 2015; Food & Agriculture Organisation of the United Nations [FOA], 2015). The annual deforestation rate is estimated at around 3% per year, which is equivalent to the loss of 410,000 hectares of forested land annually (FAO, 2015).

Nigerian economy grew by an average of 4.92 percent within the period of 1971 to 1980 before witnessing negative growth at an average of -0.18 per cent from 1981 to 1990. However, the economy returned to growth path from 1991 to 2000 at an average of 1.64 per cent. The periods of 2001-2010 and 2011 to 2015 saw an impressive growth rate average 7.97 per cent and 5.03 per cent. The oil glut led to fall in oil price culminating into recession and saw the economy trend on negative path at -1.61 per cent in the period of 2016 but returned to growth trajectory in 2021 at 3.64 per cent. But in spite of this relative growth witnessed in some years, there have being increasing concerns about shortage in the energy supply, rise in energy use and climate change in Nigeria (Ochada & Ayadi, 2020). Essentially, energy consumption is also seen as a driving force behind any economic activity and, indeed, industrial production (Zhixin & Xin, 2011). Thus, this has led to the shift to alternative sources of power subsequent increase in emission level (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 particularly linked to some solid fuels been associated with indoor pollution and unsafe levels of toxic emission (Viegi et al, 2004; Staton & Harding, 2011).

The rural-urban drift, rising population and increasing living standards has led to increase household energy consumption in Nigeria (***Oyedepo, 2014; Shaaban & Petinrin, 2014).*** These household energy consumptions leading to greenhouse gas emissions pose serious threat to rise in global warming and climate change (Akpan & Akpan, 2012; Mohammed et al., 2012). Specifically, household sector alone contributes to about 59% of the world's $CO_2$ emission, however, in Nigeria solid biomass fuels (for cooking & space heating) contributes 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 household sector accounts for about 78% of the country's total energy consumption (***Oseni, 2012),*** mostly dominated by fossil fuels and traditional solid biomass, and often regarded as major contributors 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 causes of environmental degradation (Lin & Raza, 2019).

The activities of humans involving a high use of energy poses threats to the environment and causing 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, hydro power, which some individuals cannot afford due to low income resulting from poor economic performance in Nigeria? Literature identified major drivers such as income, gender, lack of information on alternative energy system, 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 estimates 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 corroborating to the earlier finding revealing that the death of nearly 1800 people in developing cities every day as a result of poor environmental quality (WHO, 2004; Oguntoke & Adeyemi, 2017; Matthew et al., 2018). This is in addition to an average of life expectancy 47.59 in Nigeria between the period of 1971 to 2021 (World Bank, 2021). This is even more pronounced in developing countries, since poorer people are more likely to live in degraded environments. Equally, poor health outcomes in terms of low life expectancy and a subsequent high mortality have been attributed to low quality environmental/environmental degradation attendant upon 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 member on climate change policies (Vermeulen et al., 2012); and in December, 2017, also became a signatory to the Paris agreement on CO2 emission reduction target and intergovernmental panel on climate change (IPCC). Back home, there is National policy on the environment (revised 2016) targeted towards environmental protection and the conservation of natural resources. Fewer studies (Ubuoh & Nwajiobi, 2018; Maina, Kyari & Jimme, 2020; Lin and 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, thus there is need to constantly conduct this kind of study to ascertain the current situation to guide future policy formulation. Therefore, this study looks at the implication of household energy (disaggregated into soil fuel, fossil fuel & gaseous fuel consumption) on environmental quality (proxied by CO2 emission). This paper therefore is divided into five section. Section I introduction, section II Literature Review, section III Theoretical framework and Materials and Methods, section IV Results and Discussion and section V Conclusions and policy remarks.

## 2. Literature Review

### 2.1 Theoretical Framework

The theoretical framework of this study is centred on the environmental Kuznets hypothesis. The Environmental Kuznets curve hypothesis states that there is an inverted U-shape relation between environmental degradation (carbon emission) and income per capita, with pollution or other forms of degradation intensifying in the early stages of economic development and falling in the latter stages. Kuznets (1955) predicted that the changing relationship between per capita income and income inequality is an inverted-U-shaped curve. As per capita income increases, income inequality also increases at first and then starts declining after a turning point (TP). In other words, the distribution of income becomes more unequal in early stage of income growth and then the distribution moves towards greater equality as economic growth continues (Kuznets, 1955).

Ibrahim and Cudjoe (2021) employed Vector Error Correction Model (VECM) to analyse environmental impact of energy consumption in Nigeria from 1990-2018. Finding shows that charcoal consumption has a long run tendency of reducing CO2 emission while fuel wood consumption has a long run possibility of raising CO2 emission. In addition, usage of gas oil and hydroelectricity has a capacity to reduce CO2 emissions while natural gas consumption and fuel oil consumption has a detrimental impact on CO2 emission.

Maina, Kyari and Jimme (2020) analyzed the impact of household fuel expenditure on environment in Nigeria. The Ordinary Least Squares (OLS) results revealed that households dedicate greater share of their income on dirty fuels. However, the urban households were found to emit more CO2 than the rural households. The Kuznet hypothesis is also found to be applicable to Nigerian households.

Adetayo, Adeyinka and Agbabiaka (2020) examined domestic energy usage and its health implication on residents of Ese-Odo and Okitipupa Local Government Areas (LGA), of Ondo State. The result of multiple regression analysis show that environmental and socio-economic related attributes influenced residents’ choice of domestic energy type. The study further establish that burns, blind ness, stroke, cataract and pulmonary diseases were the most prevalent self-reported ill-health. However, there exist a relative weak correlation between domestic energy usage and ill-health among the residents of selected LGA of Ondo State.

Pokubo and Al-Habaibeh (2019) examines the current energy consumption mix in relation household energy use and its likely effects on the environment and health of Nigerians using descriptive statistics. Empirical findings show that electricity, firewood, charcoal and liquified petroleum gas are the main household energy sources in Nigeria. The implication is that Thus, the study concludes that fossil fuel-based energy and solid fuels for energy generation and consumption is the predominant alternative energy use. Afolayan and Aderemi (2019) adopts Dynamic Ordinary Least Square (DOLS) and granger causality to examines the relationship between environmental and health effects; and its implications for achieving sustainable economic development in Nigeria from 1980 to 2016. Findings reveal that CO2 emissions exhibit negative effect on mortality rate while electric power consumption, fossil fuel consumption exerts positive effect on mortality rate. Finding of granger causality show that life expectancy account for the causation in electric power consumption, and fossil fuel consumption causes changes in mortality rates.

Mesagan and Nwachukwu (2018) adopts ARDL bounds testing approach to conduct an analysis on urbanization, per capita income, environmental degradation, energy consumption, trade intensity, and capital investment. ARDL findings reveal that income, energy consumption, accounts for environmental degradation, Also, there exists bidirectional causality between energy consumption and environmental degradation.

Wang et al. (2018) used a vector error-correction model and found evidence of varied Granger causality relationship between energy consumption, economic growth, CO2 emissions and urbanization across the income-based subpanels. Ubuoh and Nwajiobi (2018) assessed the implications of different household cooking energy (firewood stove, kerosene stove, charcoal stove, electricity stove and gas cooker) on indoor air quality in urban and semi-urban settlements in Imo, South Eastern Nigeria. The study adopts ANOVA and results show that households' energy accounts for environmentally with fuel wood being the highest contributors compared to charcoal and kerosene. The study further show that gas cooker and electric stove cooking methods are less harmful to the environment. Matthew et al. (2018) used the ARDL approach and established a negative correlation between greenhouse gas (GHG) emissions and health outcomes in Nigeria. Specifically, the evidence reveals that increase in GHG emissions reduces life expectancy at birth in Nigeria.

Gujba, Mulugetta and Azapagic (2015) studies life cycle environmental impacts and costs of the household cooking sector in Nigeria from 2003 to 2030. Using content analysis and exploratory data analysis, finding reveal that if nothing is done, the environmental impacts would increase by up to four times and costs by up to five times, mainly because of high fuel wood consumption.

Sinha (2014) analysed the causal relationship between environmental degradation and mortality rates in India between 1971 and 2010. The outcome shows a bidirectional causal relationship between infant mortality rate and growth in CO2 emission as well as between 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 CO2 matters in the determination of the relationship between environmental quality and health outcomes.

Empirically, there are significant numbers of studies on this subject matter owing to the rising concern on the global warming and climate change that is at the forefront of world economies, reason that prompt the Paris agreement in December 2017. Essentially, it becomes imperative to frequently conduct this kind of study to ascertain the magnitude and significant of the impact to guide policy framework on household energy consumption and environmental quality. Also, previous literature revealed that about 80 per cent of total energy consumed annually is consumed by the household sector and derived from solid biomass fuels utilised for various domestic activities (Mohammed et al., 2017). This current study therefore focusses on solid fuel consumption proxied for household energy in addition to fossil fuel and gaseous fuel consumption as percentage of total energy covering the period of 1971 to 2021, which most of the studies reviewed failed to do.

## 3. Materials and Method

The study adopted an ex-post-facto research design. It sought data from secondary sources of Central Bank of Nigeria (CBN) and the World Bank's Development Indicators. The data includes solid fuel consumption as percentage of total, fossil fuel consumption as percentage of total, gaseous fuel consumption, GDP per capita and rate of urbanization. This was for the period from 1971 to 2021. This study used analytical technique of autoregressive distributed lag (ARDL) testing procedure. Other econometric diagnostic tools such as Breusch-Godfrey Serial Correlation LM Test, Heteroskedasticity Test: Breusch-Pagan-Godfrey, Ramsey RESET Test. The study further employed conventional stationarity tests like the Augmented Dickey-Fuller (ADF) proposed by Dickey and Fuller (1979). To achieve the objective of this study, the study adopts the Environmental Kuznet Curve framework which suggests that there is an inverted U-shaped relationship between household energy and environmental quality. Therefore, following Andreoni and Levinson (2001), Dasgupta et al. (2002), and Stern (2004), the EKC model is specified as follows:

$$E_t = \varphi + \beta_1 Y_t + \beta_2 Y_t^2 + \varepsilon_t \quad \text{Eqn. 1}$$

In equation (1), *E* is the environmental quality index computed from the PCA, $\boldsymbol{\varphi}$ is the intercept term, $\beta1$ and $\beta2$ are the coefficients of income per capita of the first and second derivatives respectively, $\varepsilon$ is the residual term, and *t* represents the time index. Notably, *E* is computed from CO2 emissions and particulate emissions damage (PM) in Nigeria. To accommodate other determinants of environmental quality, Mesagan and Nwachukwu (2018) modify equation (1) as follows.

$$E_t = \varphi + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 FD_t + \beta_4 EC_t + \beta_5 INV_t + \beta_6 TI_t + \beta_7 UBN_t + \varepsilon_t \quad \text{Eqn. 2}$$

According to Mesagan and Nwachukwu (2018), in equation (2), *FD* represents financial development and it is proxied by the available credit to the private sector. *EC* is the amount of energy consumed; *INV* represents the volume of capital investment, proxied by the gross fixed capital formation; *TI* is the trade intensity ratio, calculated as total trade divided by the GDP; and *UBN* is the rate of urbanization. The remaining variables are as explained in equation (1).

However, in other to ascertain the implication of household energy on environmental quality in Nigeria, the model of Mesagan and Nwachukwu (2018) was modified and stated as follows in equation (3).

$$ENQ_t = \varphi + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 SFC_t + \beta_4 FFC_t + \beta_5 GFC_t + \beta_6 UBN_t + \varepsilon_t$$

To estimate the specified model, we use the autoregressive distributed lag (ARDL) bounds testing approach. According to Pesaran and Shin (1998) and Pesaran et al. (2001), the method is built on the Wald test or F-statistic to determine the implication of the lagged values of variables in a conditional and unrestricted dynamic error correction model. Also, we use the ARDL bounds test due to the need to determine the short- and long-run effects of the explanatory variables on environmental quality, and for its superiority over other estimation techniques when the study entails a small sample. Again, in this study, we use the standard t-test and F-test to determine the strength of the lagged variables in the first difference estimation. One significant advantage of this methodology is that the F-test and t-test are applicable whether the variables are *I*(0), *I*(1) or integrated mutually. Hence, following Pesaran and Shin (1998), we estimate the following unrestricted error correction model:

$$\Delta ENQ_t = \alpha_o + \sum_{i=1}^{p} \alpha_1 \Delta ENQ_{t-i} \sum_{i=1}^{p} \alpha_2 \, \Delta V_{t-i} \beta_1 ENQ_{t-1} + \beta_2 V_{t-1} + \varepsilon_t$$

Where *ENQ* is the dependent variable, *V* stands for independent variables, *p* is the lag structure, Δ is the difference operator, $\alpha_1$ and $\alpha_2$ are the short-run estimates, $\beta_1$ and $\beta_2$ are the long-run estimates, and " is the white noise error term. For the models to be estimated in this study, the hypothesis to be tested is:

*H*0 : $\beta1 = \beta2 = ::: = \beta n = 0$ (i.e., there is no long-run relationship).

*H*1 : $\beta1$ 6= $\beta2$ 6= ::: = $\beta n$ 6= 0 (i.e., there is a long-run relationship).

Hence, using the F-test suggested in Pesaran and Shin (1998) and Pesaran et al. (2001), the estimated ARDL test statistics will be compared with the two asymptotic critical values in Pesaran et al. (2001) as against the conventional critical values. Therefore, if the estimated test statistic is higher than the upper critical value, we will reject the null hypothesis of no long-run relationship, but if it is lower than the lower critical value, we will accept the null hypothesis. However, if the estimated test statistic lies between the two critical values or bounds, then the result is inconclusive. Thus, following Pesaran and Shin (1998) and Pesaran et al. (2001), the reduced form model to be estimated in this study is specified as:

$$[4] \quad \Delta ENQ_t = c + \alpha_1 ENQ_{t\_1} + \alpha_2 Y_{t\_1} + \alpha_3 Y_{t\_1}^2 + \alpha_4 SFC_{t\_1} + \alpha_5 FFC_{t\_1} + \alpha_6 GFC_{t\_1} + \alpha_7 UBN_{t\_1} + \sum_{i=0}^{q1} \beta_{1i} \Delta ENQ_{t-1} + \sum_{i=0}^{q2} \beta_{2i} \Delta Y_{t-1} + \sum_{i=0}^{q3} \beta_{3i} \Delta Y_{t\_1}^2 + \sum_{i=0}^{q4} \beta_{4i} \Delta lnSFC_{t-1} + \sum_{i=0}^{q5} \beta_{5i} \Delta FFC_{t-1} + \sum_{i=1}^{q6} \beta_{6i} \Delta GFC_{t-0} + \sum_{i=1}^{q7} \beta_{7i} \Delta UBN_{t-0} + \mu_t$$

Where Δ is the first difference operator, $\alpha_o$ represents the drift, $\alpha_{1-7}$ are the short-run dynamic coefficients of the underlying ARDL model, $\beta_{1-7}$ represents the long-run multipliers, *t* is the time index, and $\varepsilon_t$ is the white noise error term. In equations (3, 4), *HEC* represents household energy consumption and it is proxied by solid fuel consumption as % of total. *FFC* is the amount of fossil fuel consumed; *GFC* represents the gaseous fuel consumption as % of total and *UBN* is the rate of urbanization.

## 4. Results and Discussion

Table 1: Descriptive Statistics

| | CO2 | SFC | FFC | GFC | GDPPC | UBN |
|---|---|---|---|---|---|---|
| Mean | 81832.05 | 0.38 | 17.98 | 16.36 | 0.75 | 4.74 |
| Median | 80530.00 | 0.12 | 18.63 | 14.00 | 1.47 | 4.74 |
| Maximum | 147467.00 | 2.07 | 22.84 | 36.43 | 12.46 | 5.85 |
| Minimum | 32280.60 | 0.01 | 5.97 | 1.09 | -15.45 | 4.03 |
| Std. Dev. | 25476.33 | 0.52 | 3.81 | 10.06 | 5.45 | 0.54 |
| Skewness | 0.52 | 1.80 | -1.71 | 0.25 | -0.67 | 0.43 |
| Kurtosis | 3.12 | 5.10 | 5.52 | 2.07 | 4.08 | 2.13 |
| Jarque-Bera | 2.35 | 36.91 | 38.45 | 2.37 | 6.28 | 3.17 |
| Probability | 0.31 | 0.00 | 0.00 | 0.31 | 0.04 | 0.21 |

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

Table 1 showed that all the variables have a positive mean. The maximum CO value is 147467 while the minimum is 32280.60. The maximum SFC is 2.07, whiles the minimum is 0.01. The maximum FFC, GFC, GDPPC, and UBN growth rate is 22.85, 36.43, 12.46, and 5.85 whiles the minimum is 5.97, 1.09, -15.45, and 4.03 respectively. Most of the variables were positively skewed, which implied that the variable has more increases than falls and vice-versa. The variables of GFC, and UBN have kurtosis values less than 3, which validate the property of normally distributed variables while CO2, SFC, FFC, and GDPPC have kurtosis values above 3. The Jarque-Bera for SFC, FFC, GDPPC and UBN demonstrated that the data were not normally distributed.

Table 2:Summary of Stationarity Test Results

| Variables | Augmented Dickey Fuller | | | |
|---|---|---|---|---|
| | Level | 1st Diff | Decision | Order of Integration |
| CO2 | -2.573422 | -3.3.686736*** | Stationary at level and first difference | I(1) |
| SFC | -2.390944 | -4.465809*** | | I(1) |
| FFC | -1.760627 | -4.860897*** | | I(1) |
| GFC | -1.332793 | -4.776703*** | | I(1) |
| GDPPC | -3.390944** | -5.465809*** | | I(0) |
| UBN | -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 2 reveals that GDPPC, and UBN achieve stationarity at level [that is I(0)] while the series of $CO_2$, SFC, FFC, and GFC exhibit non-stationarity at level [that is, I(0)]. To make our data stationary for all variables in our model we perform the Unit Root Test at the first difference and check for stationarity and the results reveal that the series of $CO_2$, SFC, FFC 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 3.

**Table 3: ARDL Bounds Test Result**

| Model: CO2 = f (SFC, FFC, GFC, GDPPC, UBN) | | |
|---|---|---|
| F-statistic | 9.857335*** | |
| Significance Level | Lower Bound I (0) | Upper Bound I (1) |
| 1% | 3.93 | 5.23 |
| 5% | 3.12 | 4.25 |
| 10% | 2.75 | 3.79 |

*** & ** Stands for 1% and 5% significance

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

From Table 3, the bounds tests for the cointegration relationship for the model revealed that the estimated F-statistic value of 9.857335 was higher than the lower and upper bounds values at a 1 percent level of significance. Meaning that there is a presence of cointegration relationships among the variables in the model.

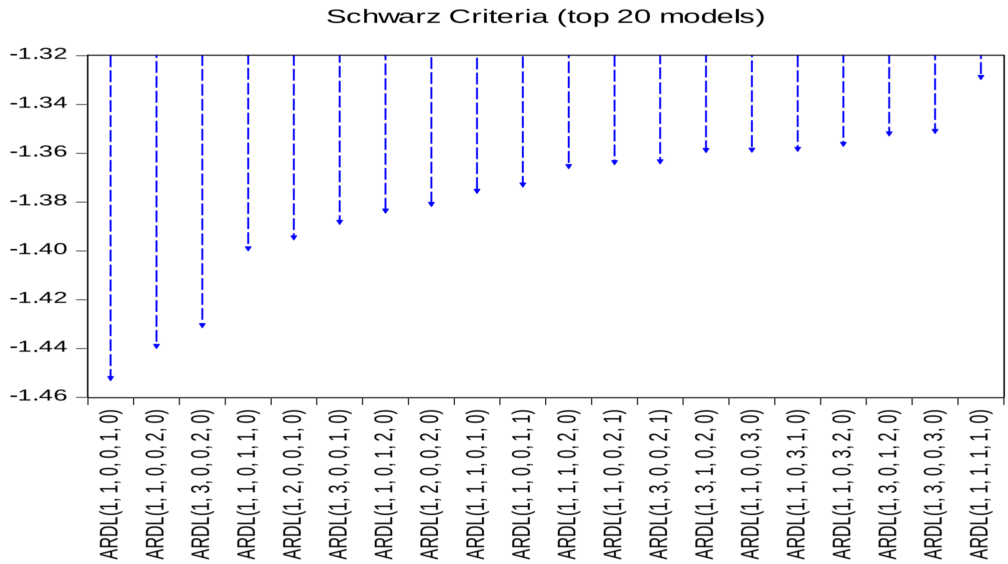


Figure 1: Lag selection criteria for linear ARDL

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

Therefore, the variables in the model are ready for the lag selection criteria test and this is 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 both linear ARDL (at the lag of 1, 1, 0, 0, 1, 0).

**Table 4: Results of the nexus between household energy and environmental quality**

| Panel A: Long run estimates | Coefficient | Std. Error | T-Stat. | Prob. |
|---|---|---|---|---|
| SFC | 0.540891 | 0.203469 | 2.658353 | 0.0112 |
| FFC | 0.051324 | 0.018017 | 2.848592 | 0.0069 |
| GFC | -0.028473 | 0.011793 | -2.414392 | 0.0204 |

| | | | | |
|---|---|---|---|---|
| GDPPC | -0.008506 | 0.005764 | -1.475551 | 0.1479 |
| UBN | -0.072702 | 0.056654 | -1.283266 | 0.2068 |
| Panel B: Short run estimates | | | | |
| Constant | 6.193657 | 1.381505 | 4.483269 | 0.0001 |
| $\Delta CO2_{t-1}$ | -0.630883 | 0.120636 | -5.229626 | 0.0000 |
| $\Delta SFC_{t-1}$ | 0.341239 | 0.098637 | 3.459548 | 0.0013 |
| $\Delta FFC_{t-1}$ | 0.032379 | 0.009552 | 3.389684 | 0.0016 |
| $\Delta GFC_{t-1}$ | -0.017963 | 0.005989 | -2.999448 | 0.0046 |
| $\Delta GDPPC_{t-1}$ | -0.005366 | 0.003796 | -1.413492 | 0.1652 |
| $\Delta UBN_{t-1}$ | -0.045866 | 0.036435 | -1.258860 | 0.2154 |
| $ECT_{t-1}$ | -0.630883 | 0.077342 | -8.157022 | 0.0000 |

**Source:** *Extract from EViews 10 Output*

The results of the estimated ARDL short run and error correction models of the study were presented in Table 4 The long-run and short-run results revealed that the coefficient of solid fuel consumption (SFC) proxied for household energy exhibits a positive impact and is statistically significant at a 1% level of significance implying that the variable has a significant positive impact on the environmental quality proxy by carbon dioxide emission (CO2) in Nigeria. Specifically, a change in solid fuel consumption by 1 percent level will bring about 0.541 percent and 0.341 increases in carbon dioxide emission (worsen environmental quality) in the long run and short run. This is expected at the early stages of development with few alternative energy sources due to limited resources to acquire environmentally friendly energy or the inability to access alternative energy sources within. The finding of this study conforms to the earlier findings of Mesagan and Nwachukwu (2018), Ubuoh and Nwajiobi (2018) Wang et al. (2018), which further validates the applicability of Kuznets hypothesis to Nigerian household's energy consumption.

Similarly, the complementary variable of fossil fuel consumption exhibits a positive effect and significant relationship with environmental quality. However, gaseous fuel consumption exerts a negative impact and significant correlation with environmental quality. This implies, that a unit change in GFC will bring about a 0.028 percent decrease in carbon dioxide emission (improved environmental quality), which is in line with the finding of Ubuoh and Nwajiobi (2018), Ibrahim and Cudjoe (2021) that gas usage is less harmful to the environment. The long-run and short-run coefficients of gross domestic product per capita (GDPPC) and rate of urbanization (UBN) demonstrate negative impact and insignificant correlation with environmental quality. Precisely, changes in GDPPC and UBN by one percent are associated with -0.008, -0.073 in the long run and -0.005 and -0.045 in the short run decreases in CO2 emission. This means that growth in GDPPC and UBN does not lead to an increase in CO2 emission. This outcome is contrary to the findings of Mesagan and Nwachukwu (2018), Maina, Kyari, and Jimme (2020)

The coefficient of ECM reported at -0.630883 is correctly signed and statistically significant at 1 per cent. This implies that it will take a 25 per cent time horizon for the short-run dynamics to equilibrate in the long run. The adjusted R-square value of 0.667719 signifies that 67% variation in environmental quality can be jointly explained by the five explanatory variables and only 33 per cent variation in gross environmental quality is explained by the error term. The Durbin Watson value of 2.405618 implies that the model is free from first-order serial correlation as the value is within the range of 1.50 to 2.50. The F-statistic which is the test for the overall significance of the model indicates the value of 25.61633 which is highly significant at a 1 per cent level of significance, meaning that the explanatory variables in the model were jointly significant in explaining the changes in environmental quality.

**Table 5: Result of Correlation Matrix**

| | CO2 | SFC | FFC | GFC | GDPPC | UBN |
|---|---|---|---|---|---|---|
| CO2 | 1.00 | -0.75 | 0.52 | 0.82 | 0.02 | -0.45 |
| SFC | -0.75 | 1.00 | -0.84 | -0.64 | 0.09 | 0.19 |
| FFC | 0.52 | -0.84 | 1.00 | 0.40 | -0.25 | 0.16 |
| GFC | 0.72 | -0.64 | 0.40 | 1.00 | -0.02 | -0.35 |
| GDPPC | 0.02 | 0.09 | -0.25 | -0.02 | 1.00 | -0.15 |
| UBN | -0.45 | 0.19 | 0.16 | -0.35 | -0.15 | 1.00 |

**Source:** *Extract from EViews 10 Output*

From the correlation matrix in Table 5 above, we can confirm that there is no pair-wise correlation coefficient that is in excess of 0.80 (Gujarati and Porter, 2006). Hence, the variables cannot be said to be collinear. SFC is -0.75, FFC is 0.52, with GFC, GDPPC and UBN having 0.72, 0.02 and -0.45 respectively. Therefore, we conclude that there is no multicollinearity among the repressors.

**Table 6: ARDL Diagnostic Test Results**

| Diagnostic Tests | F-statistic | Probability |
|---|---|---|
| Serial Correlation Test | 2.300366 | 0.1140 |
| Heteroskedasticity Test | 2.256`95 | 0.0378 |

**Source:** *Extract from EViews 10 Output*

A serial correlation test using Breusch-Godfrey serial correlation LM test was employed on the study to test for the presence of serial correlation. The null hypothesis for no serial correlation was not rejected since the p-value is greater than five per cent. Heteroscedasticity was also estimated using the Breusch-Pagan-Godfrey test and from the test result reported in Table 6, the null hypothesis of variance is constant (homoscedasticity) because the probability value is greater than five per cent.

## 5. Conclusion and Recommendations

This study looks at the implication of household energy (disaggregated into soil fuel, fossil fuel and gaseous fuel consumption) on environmental quality (proxied by CO2 emission), which is hinged on environmental Kuznets hypothesis. The study covers the period of 1971 to 2021 using data obtained from World Bank's database while the estimation technique is the ARDL and granger causality test approach. The preliminary test of stationarity test exhibit mixed order of integration [that is I(0) & I(1)], necessitating the use of the ARDL bound approach. The finding of the first objective reveals that household energy consumption proxied by solid fuel consumption account for an increase in carbon dioxide emission (worsening environmental quality) both in the long-run and short-run. Based on these findings, this study, therefore, concludes that there is still a high level of dependence on solid fuel energy consumption among Nigeria's households and if not addressed through the adoption of environmentally friend energy, it will take the Nigerian government many years to curtail the consequence of the environmental hazard, which is also harmful to human health.

## References

Adetayo, O.D., Adeyinka, S.A. and Agbabiaka, H.I. (2020). Domestic energy usage and its' health implications on residents of the Ese-Odo and Okitipupa local government areas of Ondo state, Nigeria. *Environmental Quality Management*, 2020;1–10 doi:10.1002/tqem.21681

Afolayan, O.T. and Aderemi, T.A. (2019). Environmental quality and health effects in Nigeria: implications for sustainable economic development. *SSRG International Journal of Economics and Management Studies*, 6(11), 44-55

Akpan, G. E., and Akpan, U. F. (2012). Electricity consumption, carbon emissions and economic growth in Nigeria. *International Journal of Energy Economics and Policy*, 2(4), 292-306.

Alege, P.O., Adediran, O.S. and Ogundipe, A.A. (20216). Pollutant Emissions, Energy Consumption and Economic Growth in Nigeria. International Journal of Energy Economics and Policy, 2016, 6(2), 202-207

Andreoni, J. and Levinson, A. (2001). The simple analytics of the environmental Kuznets curve. *Journal of Public Economics*, 80(2), 269-286.

Balan, F. (2016). Environmental Quality and its Human Effects: A Causal Analysis for the EU-25. *International Journal of Applied Economics*, 13(1), 57-71.

Chafe, Z.A., Brauer, M., Klimont, Z., Dingenen, Z.V., Mehta, S., Rao, S., Riahi, K., Dentener, F. and Smith, K.R. (2014). Household cooking with solid fuels contributes to ambient PM2.5 air pollution and the burden of disease. *Environmental Health Perspectives*, 122(12), 1314-1320.

Cheremisinoff, N.P. (2008). *Responsible Care. The Chemical Process Industries, 143–235.* doi:10.1016/b978-1-933762-16-6.50007-4

Dasgupta, S., Laplante, B., Wang, H., and Wheeler, D. (2002). Confronting the Environmental Kuznets Curve. *Journal of Economic Perspectives*, 16(1), 147-168

Dinh H. L. and Shih-Mo L. (2015). Dynamic causal relationships among CO2 emissions, energy consumption, economic growth and FDI in the most populous Asian countries. *Journal of Advance Management & Applied Economics*, 5(1), 1-5

Dinh H. L., and Shih-Mo L. (2015). Dynamic causal relationships among CO2 emissions, energy consumption, economic growth and FDI in the most populous Asian countries. *Journal of Advance Management & Applied Economics*, 5(1), 1-5

Emagbetere, E; Odia, J; Oreko, BU (2016). Assessment of household energy utilized for cooking in Ikeja, Lagos State, Nigeria. Nig. J. Technol. 35(4): 796 – 804.

Eregha, P.B. and Mesagan, E.P. (2017). Energy consumption, oil price and macroeconomic performance in energy dependent African countries. *Applied Econometrics*, 46:74-89.

European Environment Agency (2022). Environment and health. Available online at https://www.eea.europa.eu/themes/human/intro Accessed 30th - 07-2022

Food and Agriculture Organisation of the United Nations [FOA] (2015). *Global Forest Resources Assessment 2005*; FAO Forestry Paper 147; 2006. Available online: http://ftp://ftp.fao.org/docrep/fao/ 008/A0400E/A0400E00.pdf (accessed on 30 July 2022).

Geweke, J., Meese, R. and Dent, W. (1983). Comparing alternative tests of causality in temporal systems. Analytic results and experimental evidence. *Journal of Econometrics*, 21, 161–94.

Ibrahim, A.S. and Cudjoe, D. (2021). The Environmental Impact of Energy Consumption in Nigeria: Evidence from CO2 Emissions. Research Square, https://doi.org/10.21203/rs.3.rs-420727/v1

IEA (International Energy Agency). (2006). *World Energy Outlook*. Paris: OECD *38*(4), 247-257.

Kadiri, KO; Alabi, OA (2014). Household energy consumption pattern in Offa City, Kwara State, Nigeria. J. Sci. Research & Report, 3(11): 1499- 1506.

Kasman, A., and Duman, Y. S. (2015). CO2 emissions, economic growth, energy consumption, trade and urbanization in New EU member and candidate countries: A panel data analysis. *Economic Modelling*, 44(2), 97–103.

Kasman, A., and Duman, Y. S. (2015). CO2 emissions, economic growth, energy consumption, trade and urbanization in New EU member and candidate countries: Apanel data analysis. *Economic Modelling*, 44(2), 97–103.

Le, T., and Nguyen, C.P., (2019). Is energy security a driver for economic growth? Evidence from a global sample. *Energy Policy*, 129, 436-451.

Lin, B., and Raza, M.Y. (2019). Analysis of energy related CO2 emissions in Pakistan. *J. Clean. Prod.*, 219, 981-993.

Maina, Y.B., Kyari, B. and Jimme, M.A. (2020). Impact of household fuel expenditure on the environment: the quest for sustainable energy in Nigeria. *Central Asian Journal of Environmental Science and Technology Innovation*, 2 (2020) 109-118

Matthew, O., Osabohien, R., Fasina, F. and Fasina, A. (2018). Greenhouse Gas Emissions and Health Outcomes in Nigeria: Empirical

Insights from ARDL Technique. *International Journal of Energy Economics and Policy*, 8(3), 43-50.

Matthew, O., Osabohien, R., Olawande, T. and Urhie, E. (2019). Manufacturing Industries and Construction Emissions in Nigeria: Examining the Effects on Health Conditions. *International Journal of Civil Engineering and Technology*, 10(01), 2401-2414.

McGranahan, G. and Kaijser, A. (1993). Household Energy - Problems, Policies and Prospects. Stockholm Environmental Institute, Box 2142, S-10314, Stockholm, Sweden.

Mensah, J.T., and Adu, G., (2015). An empirical analysis of household energy choice in Ghana. *Renewable and Sustainable Energy Reviews*, 51, 1402-1411.

Mesagan, E. and Ekundayo, P. (2015). Economic Growth and Carbon Emission in Nigeria. *IUP Journal of Applied Economics*, 3(2), 44-56.

Mesagan, E.P. and Nwachukwu, M.I. (2018). Determinants of environmental quality in Nigeria: assessing the role of financial development. *Econometric Research in Finance*, 3, 55-78

Mohammed, A., Ismat, A., Jeroen, B., & Guido, V.H. (2012). Energy consumption, carbon emission and economic growth nexus in Bangladesh: Cointegration and dynamic causal analysis. Energy Policy Journal, 45(2) 217 – 225.

Mohammed, Y.S., Mustafa, M.W., Bashir, N. and Ibrahem, I.S., (2017). Existing and recommended renewable and sustainable energy development in Nigeria based on autonomous energy and microgrid technologies.

Nasiru, I.M. (2015). Desertification in the Dry Lands of Nigeria and its Consequences. Available online: http://fab.utm.my/wp content/uploads/2011/10/cStudents_student3 Seminar200708.pdf (accessed on 30 July 2022).

Oguntoke, O. and Adeyemi, A. (2017). Degradation of Urban Environment and Human Health by Emissions from Fossil Fuel Combusting Electricity Generators in Abeokuta Metropolis, Nigeria. *Indoor and Built Environment*, 26(4) (2017) 538-550.

Onakoya, A.B., Onakoya, A.O., Jimi Salami, O., and Odedairo, B.O. (2013). Energy consumption and Nigerian economic growth: An empirical analysis. *European Scientific Journal*, 9(4), 25-40

Oseni, M.O., (2012). Households' access to electricity and energy consumption pattern in Nigeria.

Oyedepo, S.O. (2014). Towards achieving energy for sustainable development in Nigeria. Renewable and Sustainable Energy Reviews, 34, 255-272.

Pesaran, M.H. and Shin, Y. (1998). An autoregressive distributed-lag modelling approach to cointegration analysis. *Econometric Society Monographs*, 31, 371- 413.

Pesaran, M.H., Shin, Y., and Smith, R.J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289-326.

Pokubo, D. and Al-Habaibeh, A. (2019). An investigation into the current household energy consumption mix in Nigeria. International Conference on Energy and Sustainable Future, Nottingham, UK, 9-11 September 2019.

Schlag, N. and Zuzarte, F. (2008). Market barriers to clean cooking fuels in sub-Saharan Africa: a review of literature.

Shaaban, M., and Petinrin, J.O. (2014). Renewable energy potentials in Nigeria: Meeting rural energy needs. *Renewable and Sustainable Energy Reviews*, 29, 72-84.

Sharma, S. (2017). Climate Change and Sustainability. *SSRG International Journal of Economics and Management Studies*, 4(6) (2017) 21-26.

Sinha, A. (2014). Carbon Emissions and Mortality Rates: A Causal Analysis for India (1971-2010). *International Journal of Economic Practices and Theories*, 4(4) (2014) 486-492

Staton, D.M. and Harding, M.H. (2011). Health and environmental effects of cooking stove use in developing countries. 2000. Cited 22-11-2011.

Stern, D.I. (2004). The Rise and Fall of the Environmental Kuznets Curve. *World Development*, 32(8), 1419-1439

Ubuoh, E.A. and Nwajiobi, B. (2018). Implications of Different Household Cooking Energy on Indoor Air Quality in Urban and Semi-Urban Settlements in Imo, South Eastern Nigeria. *J. Appl. Sci. Environ. Manage*, 22 (5), 725 – 729 May 2018

Uddin, G. A., Salahuddin, M., Alam, K., and Gow, J. (2017). Ecological footprint and real income: Panel data evidence from the 27 highest emitting countries. *Ecological Indicators*, 77(2), 166–175.

Unicef, (2019). Silent Suffocation in Africa Air Pollution is a Growing Menace, Affecting the Poorest Children the Most. Available online at https://www.unicef.org/media/55081/file/Silent_suffocation_in_africa_air_pollution_2019.pdf

Vermeulen, S.J., Campbell, B.M., and Ingram, J.S. (2012). Climate change and food systems. *Annu. Rev. Environ. Resour*., 37(1), 195-222.

Viegi, G., Simoni, M., Scognamigli, A., Baldacci, S., Pistelli, F. and Carrozzi, L. (2004). Indoor air pollution and airway disease. *Int J Tuberc Lung D*, 8(12),1401- 15.

Wang, Q., Kwan, M., Zhou, K., Fan, J., Wang, Y. and Zhan, D., (2019). Impacts of residential energy consumption on the health burden of household air pollution: Evidence from 135 countries. *Energy Policy*, 128, 284-295.

Wang, S., Li, G. and Fang, C. (2018). Urbanization, economic growth, energy consumption, and CO2 emissions: empirical evidence from countries with different income levels. Renew. *Sustain. Energy Rev*. 81, 2144–2159. July 2017.

Wang, Z; Zhang, B; Yin, J; Zhang, Y (2011). Determinants and policy implication of household electricity saving behaviour: Evidence from Beijing China. Energy Policy 39, 3550-3557.

WDI, (2019). World Bank's world development indicators. Available at: http://www.world bank.org/.

WHO (2006). Fuel for Life: Household Energy and Health. Available online at https://apps.who.int/iris/bitstream/handle/10665/43421/9241563168_eng.pdf Accessed 30th-07-2022

World Health Organisation (2015). Indoor Air Pollution: National Burden of Disease Estimates 2007. Available online: http://www.who.int/indoorair/publications/indoor_air_national_burden_estimate_revised.pdf (accessed on 30 July 2022).

World Health Organization, WHO., The 10 Leading Causes of Death by Broad Income Group. Available from: www.who.int/mediacentre/factsheets/fs266/en/index.html; last accessed 30 July 2022.

Wuyuan, P., Zerriffi, H. and Jihua, P. (2008). Household level fuel switching in rural Hubei.

Zhixin, Z. and Xin, R. (2011). Causal relationships between energy consumption and economic growth. *Energy Procedia Elsevier Ltd*., 5 (2) 2065–2071