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Climate Change, Poverty and Income Inequality Linkage: Empirical Evidence from Nigeria

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ABSTRACT

There seems to be a vicious cycle between climate change and income inequality. Hence, this study examined the existence of a feedback relationship between climate change and income inequality in Nigeria. The study employed an annual data series for the period from 1980 to 2020 which was estimated with the Dynamic Ordinary Least Square. Income inequality was measured by Gini while climate change was captured by temperature. The upshot of the study revealed that there is a feedback substantial connectivity between climate change and income inequality. The impact of climate change on income inequality conformed to the U-shaped hypothesis. Other factors of climate change were population growth, economic development, and emission of carbon dioxide. Hence, the study pertinently advocates and recommends effective population control, reduction of income inequality through the provision of employment and education, and the supply of modern and efficient energy in the purse of economic growth and development.

Keywords: Climatic Change, Economic Development, Gini Coefficient, Poverty; Nigeria
JEL Classifications: C32, I32, O15, Q0

1. INTRODUCTION

In the last decades, the growth in global output has increased the welfare of many, lifting millions out of poverty. However, this drive is being threatened by global and regional poverty, and inequality beginning to rise again. An understanding of the causes of these is crucial for effective policy implications and achieving global equitable economic development. Suspected among these causes is climate change. World Bank reported that about 132 million people will transition into poverty by 2030 due to the rising climate change (Internal Displacement Monitoring Center, 2018; World Bank, 2020). This is also expected to increase the inequality between and within countries. In a report by United Nations, an estimate of US$ 383 million/day was recorded for global economic loss resulting from the disaster of climate change between 2010 and 2019 which is almost seven times the record of 1970-1979, US$ 49 million (World Meteorological Organization, 2021).

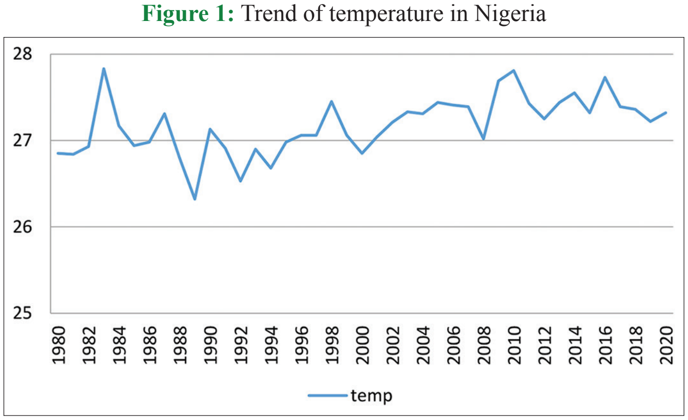
It is of recent decades becoming clear that climate change, poverty, and income are inextricably linked and not independent. Unmitigated climate change is suspected to exacerbate the existing inequality between and within countries' inequalities and poverty rates. Higher temperatures reduce productivity, income, and health. Hurricanes from climate change also destroy homes and hamper employment opportunities, making the economic situation of the poor more precarious. On the other hand, poor people and countries do not have enough resources to meet up with the requirement of clean energy to mitigate climate change hence, contributing to rising climate change (Albu and Albu, 2020). It has been suggested that the total damages from natural disasters and higher temperatures are higher in developing countries.

As confirmed by Sarkodie and Strezov (2019) in a study on 192 United Nations, Africa has been noted to be among the most venerable to climate change. For instance, near-surface air temperature in 2020 was between 0.5°C and 0.88°C more than what was recorded between 1981 and 2010, and Africa was found to be warmer than the global average temperature in the combination of overland and Ocean (World Meteorological Organization, 2020). For the period 2015-2019, each year was warmer than all the years before 2014 (World Meteorological Organization, 2020). Sub-Saharan Africa has also been found to be among the regions with the highest level of poverty and inequality. About 41% of the population is still living below the $1.90 poverty line, while it was estimated that about 87% of the world's poor will be in SSA by 2030. Africa is also the second most unequal continent in the world (Seery et al., 2019).

Nigeria in Sub-Saharan Africa has been of particular interest in terms of the level of climate change, poverty, and inequality. Temperature as a measure of climate change was found by data to have risen from 26.85°C to in 1970 to 27.37°C in 2020. This is an average of 0.03°C per decade and in the last 30 years, it increased by 0.19°C per decade. Average rainfall increased from 1295 to 2018 (World Meteorological Organization, 2020). It was estimated that about 83 million of the total population of Nigeria's population are still absolutely poor. Inequality measured by the Gini index was found to be 44% in 2019 which grew marginally from 43% in 2009 and is the lowest among other countries in SSA and the world. Nigeria ranked the least of the 45 countries in Africa and had 157 positions in the global ranking on the assessment of the government's commitment to reducing inequality (Seery et al., 2019; World Bank, 2020).

An overview of Figure 1 showed that changes in poverty and inequality seem to be moving in the same direction as climate change captured by temperature in Figure 2. Although, the temperature seems to be more dynamic. Thus, we may argue that climate changes are a foremost contributor to the wider inequality gap given the high negative effect on agricultural productivity, health, and income thereby increasing the poverty rate (poverty tends to be highest in the agricultural sector). On the other hand,

Figure 1: Trend of temperature in Nigeria



Source: Authors' chart

it may also be argued that the high level of income inequality and poverty are contributing to the effect of climate change as the unequal income distribution and poverty reduces the ability to mitigate climate change as well as engage in clean energy uses that reduces the degree of climate change. For instance, in 2016, about 74% of the country's population relied on firewood for cooking (Monyei et al., 2018), while only about 55.4% have access to electricity as of 2019 (World Bank, 2021). In the same period, poverty increased from 48.2% in 2015 to 72% in 2016. Temperature also increased from 27.32°C to 27.77°C. Hence, climate change may be a root or a corollary of some levels of inequality and poverty. Hence, it has become paramount to analyze this nexus concerning Nigeria and the outcome may be extended to other countries for effectiveness in the policy formulation for poverty and income inequality reduction as well as climate change mitigation.

Analysis of the impacts and causes of climate change has substantially increased over the decades with controversial findings. Some empirical evidence concluded that countries with lower income inequality tend to contribute less to climate change, hence suggesting across countries lower inequality for the mitigation of climate change and adoption of a green economy (Albu and Albu, 2020). Climate change has also been found to increase inequality both within counties and across countries (Di□enbaugh and Burke, 2019; Hsiang et al., 2019; Dasgupta et al., 2020). Others noted that climate change negatively impacts welfare and falls heavily on the poor increasing the poverty level (Skoufias, 2012).

In Sub-Saharan Africa and Nigeria in particular, there are very few studies (Skoufias, 2012) that found that the impact of climate change varies with the pattern of income inequality on the impact of climate change on inequality. However, rather than just focusing solely on climate-specific policies given their impact on the global economy, inequality, and poverty, it is also imperative to ask how efforts of the global economy and developing countries to improve economic opportunity and reduce poverty and inequality can increase climate change and its vulnerability. It is also crucial to ask if the level of poverty and income inequality is increasing the risk of climate change. This is based on the assumption that with poverty and a wide income gap, the poor tend to carry out activities that cause harm to the climate (deforestation for wood fuel, burning of charcoal, dumping of refuse in rivers, among others).

Hence, it can be argued that while climate change can impact inequality and poverty, poverty and inequality can impact climate change. This is a gap that has not been covered particularly in Nigeria. Hence, the current study is out to fill this gap. Therefore, the objective of this study is to determine if there exists a feedback impact between climate change, poverty, and inequality in Nigeria. This study, therefore, contributes to current literature in the following ways: first, it evaluates the possibility of a feedback effect between climate change and income inequality. Second, it made use of the efficient measures of climate change (temperature) which has not been considered in Nigeria Studies. Third, it explored the existence of a non-linear relationship between income inequality and climate. It is expected that there will be feedback connectivity between climate change and income inequality.

2. REVIEW OF LITERATURE

The impact of climate change on inequality and poverty is a particular area of active research and policy interest, as a result of the inconclusive outcome on the nature and causes of observed inequality. This is a result of the relevance of climate change in achieving sustainable development. Climate change according to Yue and Gao (2018) is the increasing patterns of temperatures and weather that bring about environmental degradation and impact economic and social lives. Climate change is mainly caused by the emission of greenhouse gas which causes heat to be trapped by the atmosphere earth's atmosphere resulting in global warming. Poverty is often defined with various measures. Defining poverty in terms of income, we have income poverty which is the lack of enough income to live up to the acceptable standard of living or pleasurable well-being. In terms of lack of basic needs of life, we have basic needs poverty which defines a person to be poor when he/she lacks needed food, education, health care, and other necessities of life. Poverty can also be defined in comparison to a universally acceptable income level which is absolute poverty. One is called poor if they are living below this level called the poverty line. Poverty can also be defined as relative poverty, chronic poverty, and transitory poverty (Todaro and Smith, 2011).

Climate change is theoretically linked with poverty and inequality through the pursuit of development and resulting in a vicious cycle. Climate change can be exogenous to inequality or endogenous to inequality, hence suggesting a feedback relationship. Given the existence of income inequality, this will make some people poor. Climate change is exogenous and three ways have been identified by which climate change can affect poverty and inequality. Poverty and inequality increase the possibility of exposure of disadvantaged groups to the adverse effect of climate change. A major outcome of climate change is flooding. Given that poor and disadvantaged groups can only afford to live in slums, these areas are often flooded. Hence the flooding effect of climate change affects the poor group more. Climate change also aggravates the susceptibility of the poor group to the effect of climate change as a result of the poor quality of life. Finally, the poor and disadvantaged have a lower ability to manage and come out of the effect of climate change. They do not have enough resources to protect their health status or take care of health effects, easily get a new job/start a new investment if their current job/investment is negatively affected by climate change, or afford an insurance policy to compensate for the damage from climate change. All these aggravate the inequality gap and poverty status of the group.

Climate change is also endogenous, the poor and disadvantaged groups are forced to engage in activities that cause harm to the climate resulting in climate change. As observed by Islam and Winkel (2017), and evidenced by studies on OECD, inequality and poverty aggregate environmental degradation contributing substantially to climate change. Countries with higher inequality tend to have higher levels of per capita waste generation. In line with the above, it may be expected that countries with higher inequality will tend to have higher levels of per capita GHG emissions change in climate in turn relatively affect the poor and the unequally treated group of the society. Inequality thus aggravates climate change (Islam and Winkel, 2017).

Thus, given this possible endogeneity as presented in Figure 3a and 3b, it has become important and urgent to tackle the task of breaking the vicious cycle between climate change and inequality.

Some earlier studies have been carried out to investigate this analytical framework. However, the outcome of these studies has been mixed results. Analyzing the existence of a feedback relationship between climate change and income inequality, the diverse impact of income inequality was found on climate change. Farmers are often believed to be the most vulnerable to climate change as a result of their direct and indirect dependency on climatic variables. Hence, Alam et al. (2017) analyzed the socioeconomic impacts of climatic changes on the farmers in Malaysia they employed a primary data analysis method on a survey of 198 paddy farmers in the Integrated Agricultural Development Area in North-West Selangor of Malaysia in 2009. The outcome showed that climate change adversely affects agricultural productivity, health, and profitability thereby increasing income inequality. Government spending through subsidies was found not to be adequate to support the farmers and reduce the effects of climate change on the farmers. This was contrary to Boyce (2007) who found that inequality brings about a reduction in carbon emission and hence climate change.

Abaje and Oladipo (2019) investigated the impact of the recent changes in temperature and rainfall in the Kaduna State of Nigeria for the period 1971-2016. Linear regression, second-order polynomial, standard deviation, and Cramer's test were employed in the analysis. The result showed an increasing trend in temperature which was on an average of 1.03°C and a mean increase of rainfall of 303.32 mm. This increase was found to be associated with the increase in greenhouse gases emission.

Uzar and Eyuboglu (2019) examined the effect of CO_2 emissions on income distribution in Turkey for the period 1984-2014. The Autoregressive Distributed Lag Model (ARDL) bound testing was employed to determine the existence of long-run connectivity among the variables. The study found that there is a positive impact of income inequality on the emission of CO_2. Income inequality Granger causes CO_2 emission using the Toda-Yamamoto causality test.

Dasgupta et al. (2020) carried out a quantitative study on climate change's impacts on inequality and poverty on a South African sub-national panel study. In conformity to Alam et al. (2017), the outcome revealed that a substantial relationship exists between inequality/poverty and mean temperature which was a measure of climate change. Climate change was found to reduce average growth, hence increasing inequality and poverty.

In a similar study to that of Uzar and Eyuboglu (2019), Kusumawardani and Dewi (2020) investigated the effect of income inequality on climate change captured by carbon dioxide emissions in Indonesia. They employed an Autoregressive Distributed Lag (ARDL) model for the period 1975-2017. Income inequality was found to harm carbon dioxide which was found to be a function of the level of GDP per capita. Thus, the existence of the Environmental Kuznets Curve (EKC) was confirmed in Indonesia and the relationship between GDP per capita and CO_2 emission was found to be an inverted "U" shape. Urbanization and dependency were found to negatively affect CO_2 emissions.

Albu and Albu (2020) explored the connectivity between income inequality and climate change in European Union countries. They accounted for the consequences of the increase in carbon emissions on the increase in inequalities. The two-stage OLS estimation method was applied to two groups of European Union countries, (15 old member states and 13 new member states). The relationship between income inequality and carbon emission was different for the two groups.

In the analysis of the effect of income inequality, poverty, and growth on the quality of the environment captured by carbon emission rate, Yameogo, and Dauda (2020), employed the ARDL model on data for Nigeria and Burkina Faso for the period 1980-2016. The result showed inverted U-Shaped connectivity between environmental degradation and growth of income for Nigeria while U-shaped connectivity was found for Burkina Faso. There was a positive relationship between income inequality and environmental degradation in both countries. Government expenditure and poverty were found to increase the level of carbon emission in Nigeria in the long run. In the short run, income inequality was found to reduce carbon emissions in Nigeria and it had an adverse effect in Burkina Faso.

Following this is the study of Sam et al. (2021) who adopted the micro econometric empirical analysis to analyze the effect of climate change on household welfare through the rising prices of cereal. Data on five food groups were gathered from the 2009/2010 Swaziland Household Income Expenditure Survey and was analyzed by the Ideal Demand System (AIDS). Also, the food price projections of the International Food Policy Research Institute (IFPRI) were employed to estimate the proportional increase in income that is needed to keep the households on the required welfare level. Results showed that an increase in food prices as a result of climate change has led to an increase in the poverty rate of about 71-75 % as compared to 63% before the increase in prices. Hence, an income transfer of 17.5 and 25.4% of the former income level is needed to keep welfare at the level before the price increase.

Hundie (2021) explored income inequality, economic growth, and carbon dioxide emission linkage in Ethiopia. The study made use of the ARDL bond testing and the Dynamic Ordinary Least Square method of estimation over the period 1979-2014. The result revealed that in the long run, the emission of CO_2 increases with the increase in economic growth and the square of economic growth confirming the Kuznets U curve hypothesis of environment. Income inequality was found not to have a substantial effect on $CO_2$and a positive relationship with it. Population size and urbanization were other factors accounting for the increase in the emission of CO_2.

Yang et al. (2022) examined the impact of the channel between income inequality and climate change (carbon emissions) to clarify the nonlinear relationship between income inequality, and the different degrees of carbon emissions in the United States and France from 1915 to 2019. They made use of wavelet decomposition and Quantile-on-Quantile regression and the results revealed that for France, income inequality impacts carbon emissions negatively when there is low-income inequality. However, when income inequality increases, its impact changes from negative to positive which is amplified by the increase in the emission of carbon emissions. On the other hand, as income inequality becomes deeper, the emission-enhancing effect is reversed gradually for the United States. However, the impact of carbon emissions on income inequality are same for both countries. In the short run, the income inequality and carbon emissions relationship in the two countries are randomly volatile while in the medium run, it is a three-dimensional inverted "V" shaped relationship for the US and a three-dimensional "V" shaped relationship for France. Also, in the long run, it exhibits a "V" shaped relationship with the US.

In a more recent study by Cevik and Jalles (2022) on the linkage between climate change and income inequality, a panel of 158 countries was explored spanning the period 1955-2019. The researchers found that the increase in climate change vulnerability leads to an increase in income inequality. On segmentation of the sample size, it was revealed that there was no statistical impact of climate change vulnerability on income inequality for the developed countries while the reverse was the case for developing countries. This was accounted to the weak capacity of adaptation and mitigation by the developing countries.

2.1. Summary of Reviewed Literature and Contribution to Knowledge

The analysis of connectivity between climate change and inequality has been examined by some studies. In summary, the studies tend to conclude that climate change increases income inequality. This was for within the countries and, across countries. Most of the studies investigated a one-way relationship between climate change and income inequity/poverty. The majority of the study found climate change increasing poverty rather than inequality d poverty increasing climate change. However, needed attention has not been drawn to the fact that there is a two-way relationship between climate change and inequality/poverty. While it is well recognized that climate change causes and aggravates inequality, it is also important to note that inequality can also aggravate climate change. This is the major contribution of this current study to existing literature.

3. METHODOLOGY

Two major determinants of climate change are rainfall and temperature. However, we focused only on temperature.

3.1. Conceptual Framework

The study adopted the approach of Burke et al. (2015b), and Dasgupta et al. (2020) to determine the non-linear relationship between climate change mean temperatures and our economic outcome variables (yit). This current study made use of normal levels of dependent variables rather than the first difference as in Burke et al. (2015b) and Dasgupta et al. (2020). A country responds to changes in temperature based on the country's current level of temperature at a particular time, T_t. taking the quadratic state can be given as:

$$hTt = \alpha_1 Tt + \alpha 2T^2t \quad (1)$$

We can then add the warming impact h(Tt) to the reference scenarios without the climate impacts of the variable yit. We look at the distribution within a country, and, we considered income inequality indices such as the Gini index or the Atkinson measure A(Ω) of inequality or the class of Generalized Entropy Indices. The poverty headcount ratio P_0 can also be used which measures the proportion of the population that is counted as poor Dasgupta et al. (2020). However, this study made use of the Gini index as a measure of income inequality as a result of its simplicity and general acceptability. Thus, the impact of climate on income inequality can be computed and simulated using this formula;

$$GNIt = \frac{GNIt - 1\ (1 + gt + (h(Tt) - h(T0))\ |}{e^{g}} \tag{2}$$

Where e^g is the growth factor including climate impacts or g is its growth rate.

The equation 2 result shows the effect of temperature on GNI in a given country at a particular time *t*.

3.2. Econometric Model

Based on the theoretical under pinning that there could be a feedback relationship between climate change and inequality given the poverty level, thus study adopts a two equation model.

$$GNI_t = \alpha_1 T_t + \alpha_2 T^2_t + \alpha_3 POV + \alpha_4 X_t + \mu_1 \tag{3}$$

$$T_t = \beta_1 GNI_t + \beta_2 POV_t + \beta_3 Z_t + \mu_2 \tag{4}$$

We control for annual temperature Tit and its squared term to capture the potential non-linear effects of climate change on income inequality. This was to test if an inverted U-shaped relationship exists between climate change and income inequality, taking into account the possibility that these relations are not linear. Inequality may decrease due to initial increases in temperature, but, beyond a threshold, the incremental increases in temperature may lead to increased inequality. Thus, it is expected that for some set of coefficients of temperature, T1 < 0; T2 > 0. In this case, the results indicate a non-linear relationship.

The term X_t and X_t are the matrix of other relevant control variables of the income inequality (unemployment rate and population growth) and relevant control variables of the climate change (carbon dioxide (metric tons per capita), Real GDP per capita, unemployment rate, population growth).

From the above, equation 3 and 4, introducing the control variables is transformed to:

$$GINI = \alpha_0 + \alpha_1 T_t + \alpha_2 TSQ + \alpha_3 POV + \alpha_4 UNMPR + \alpha_5 POPG + \varepsilon t \tag{5}$$

$$T = \beta_0 + \beta_1 GINI_t + \beta_2 POV + \beta_3 UNMPR + \beta_4 POPG + \beta_5 CADIOX + \beta_6 RGDPpc + ut \tag{6}$$

Where
GINI = Gini Index a measure of income inequality
T = Temperature a measure of climate change
POV = National poverty level captured by headcount
UNMPR = Unemployment rate
POPG = Population growth rate
RGDPpc = Real Gross Domestic product per capita. This was used to captured the level of development
CADIOX = Consumption of coal in a thousand short tons

ε_t and u_t are the error term for the income inequality and climate change equations respectively.

εt and *ut* are the error term for the income inequality and climate change equations respectively.

A Priori,

$$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6 > 0; \beta_{1,} \beta_2, \beta_{3,} \beta_{4,} \beta_5 > 0\ \beta_6 < 0$$

3.3. Data and Estimation Method

The study employed secondary data spanning from 1980 to 2020. The data for GINI, POV, and UNMPR were obtained from the World Bank (2021) and Sasu (2022). Data for temperature was acquired from Climate Change Knowledge Portal (2021), while the RGDPpc, POPG, and CADIOX were obtained from the World Development Indicators (2021). The variables were subjected to various pre-estimation tests to determine their diagnostic properties. The ARDL bounds testing was employed to determine the presence of a long-run relationship given that the variables were stationary at orders one and zero. From the outcome of the ARDL result, the dynamic ordinary least Square method of estimation was used in carrying out the long-run analysis. The E-views 9 econometric package was used for the analysis.

4. EMPIRICAL PRESENTATION AND INTERPRETATION OF RESULTS

4.1. Correlation Result

The intensity of multi-collinearity among the variables was determined using the correction matrix.

The result from Table 1 showed that there is no multi-collinearity among the variables used in the result. This is proved by the correction coefficients of less than 0.8 for the variables. However, the correlation coefficient between temperature and temperature square of 0.9999 is not surprising as the latter was derived from the former hence, they tend to move together. The result further revealed that there is a positive correlation between inequality and temperature. This tends to suggest that climate change leads to inequality and vice-versa. However, the correlation does not indicate causation hence a further empirical analysis was carried out.

4.2. Descriptive Statistics

As presented in Table 2, the mean, maximum, minimum, and Jargue-Bera (J.B) of the variables showed good performance in the statistics of the variables. The result of the skewness showed that result that all of the variables are positively skewed. The Jargue-Bera test, on the other hand, confirmed distributional

Table 1: Correlation matrix result

Variables	GINI	T	TSQ	POV	POPG	RGDPpc	UNMPR	CADIOX
GINI	1.000000							
T	0.077048	1.000000						
TSQ	0.077078	0.999965	1.000000					
POV	0.638624	0.425834	0.424772	1.000000				
POPG	−0.226438	0.184657	0.185821	−0.216889	1.000000			
RGDPpc	0.099989	0.543493	0.543516	0.315193	0.578165	1.000000		
UNMPR	0.200912	0.401293	0.401862	0.422842	0.285371	0.711676	1.000000	
CADIOX	−0.597379	0.080869	0.079646	−0.449570	0.448070	0.095579	0.014362	1.000000

Source: Author's computation. GINI: Gini Index a measure of income inequality, T: Temperature a measure of climate change, POV: National poverty level captured by headcount, UNMPR: Unemployment rate, POPG: Population growth rate, RGDPpc: Real Gross Domestic product per capita, CADIOX: Consumption of coal in a thousand short tons, TSQ: Temperature square

Table 2: Descriptive statistics

Statistics	GINI	T	TSQ	POV	POPG	RGDPpc	UNMPR	CADIOX
Mean	43.06195	27.17659	738.6741	54.52902	2.587127	1799.386	11.43598	0.610519
Median	43.00000	27.21000	740.3841	59.30000	2.586546	1607.238	11.90000	0.610000
Maximum	56.00000	27.83000	774.5089	72.90000	2.849252	2563.900	33.28000	0.928241
Minimum	35.08000	26.32000	692.7424	35.20000	2.488785	1324.297	3.600000	0.325560
SD	4.470221	0.331577	18.00321	12.23253	0.078620	450.5880	6.328673	0.169989
Skewness	0.667670	−0.181138	−0.145911	−0.247856	0.823394	0.473706	1.021092	−0.075513
Kurtosis	3.623020	2.983925	2.954869	1.616939	4.077668	1.590788	4.690907	2.064996
Jarque-Bera	3.709285	0.224649	0.148962	3.687588	6.616846	4.925921	12.00904	1.532446
Probability	0.156509	0.893754	0.928225	0.158216	0.036574	0.085182	0.002468	0.464765
Sum	1765.540	1114.240	30285.64	2235.690	106.0722	73774.82	468.8750	25.03129
Sum square deviation	799.3150	4.397722	12964.62	5985.394	0.247245	8121182.	1602.084	1.155851
Observations	41	41	41	41	41	41	41	41

Source: Authors' computation from Eviews 9. GINI: Gini Index a measure of income inequality, T: Temperature a measure of climate change, POV: National poverty level captured by headcount, UNMPR: Unemployment rate, POPG: Population growth rate, RGDPpc: Real Gross Domestic product per capita, CADIOX: Consumption of coal in a thousand short tons, SD: Standard deviation, TSQ: Temperature square

normality in all the variables. This means that all of the variables are distributed regularly

4.3. Stationarity Test

To determine the level of stationary of the variables, the Augmented Dickey-Fuller test was employed. As presented in Table 3 while income inequality and population growth were stationary at levels, other variables were stationary at first difference. Hence, we proceed to run a cointegration analysis using the ARDL bound testing techniques.

4.4. Cointegration Test

From the result of the unit root where some of the variables were integrated of order one and zero. The bound testing method was thus employed to determine the existence of cointegration between climate change and income inequality. From the income inequality model, the result showed that there is the existence of cointegration between the variables at the lower bound only at a 5% level of significance. This is as shown from the F sat of 2.717687 which is higher than the tabulated value of 2.62 lower bound but lower than 3.79 upper bound. Hence, we conclude that there is cointegration between the variables (Table A1 of the appendix).

Also, from the climate change model, the existence of cointegration was also found at a lower bound of 5% significance levels. The Fsat of 2.661207 which is more than the tabulated values of 2.45 but lower than 3.61 uppers bound respectively allowed us to reject the null hypothesis of no cointegration between the variables (Table A2 of the appendix).

Table 3: Summary of the unit-root tests output employing the ADF

Variable	Levels	5% critical	1st difference	5% critical	Remark
GINI	−3.139398	−2.936942			I (0)
T	−1.948335	−2.941145	−8.101568	−2.941145	I (1)
T^2	−1.958416	−2.941145	−8.075350	−2.941145	I (1)
POV	−1.712944	−2.938987	−10.99401	−2.938987	I (1)
POPG	−5.311883	−2.960411			I (0)
RGDPpc	−0.580213	−2.938987	−4.569165	−2.938987	I (1)
UNMPR	−0.124458	−2.938987	−7.205141	−2.938987	I (1)
CADIOX	−2.303747	−2.936942	−6.876319	−2.938987	I (1)

GINI: Gini Index a measure of income inequality, T: Temperature a measure of climate change, POV: National poverty level captured by headcount, UNMPR: Unemployment rate, POPG: Population growth rate, RGDPpc: Real Gross Domestic product per capita, CADIOX: Consumption of coal in a thousand short tons

4.5. Estimation of the Models

4.5.1. Estimation of income inequality model

From the outcome of the cointegration test carried out where the null hypothesis of cointegration was rejected, we proceed to the estimation of the model using the dynamic OLS.

Table 4 shows the DOLS o the inequality model. Examining the diagnostic statistics of the result the R^2 of 0.675073 showed that about 68% of the variation in the dependent variable is explained by the independent variables which is not bad. On the performance of the variables of the model, the outcome of the estimation showed that there is a negative relationship between temperature (T) and income inequality (GINI) and a positive relationship

Table 4: Dynamic ordinary least square estimation of the income inequality model

Dependent variable=Income inequality Method=DOLS Diagnostics: R^2=0.675073			
Independent variable	**Coefficient**	***t*-sat**	**Probability**
T	−1279.193	−2.519587	0.0220*
TSQ	23.50179	2.504725	0.0227*
POV	0.377314	4.543038	0.0003*
UNMPR	−0.318333	−1.556236	0.1381
POPG	19.06347	1.020289	0.3219
C	17380.76	2.525623	0.0218

*Source: Authors' computation, **Significant at 5% and 10% level respectively. DOLS: Dynamic ordinary least square, TSQ: Temperature square, T: Temperature a measure of climate change, POV: National poverty level captured by headcount, UNMPR: Unemployment rate, POPG: Population growth rate

Table 5: Dynamic ordinary least square estimation of climate change model

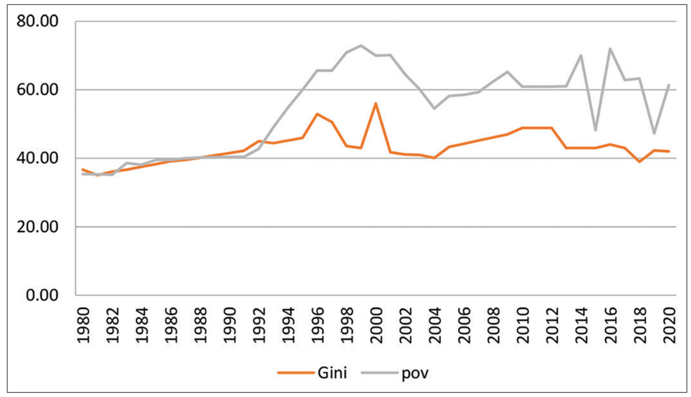
Dependent variable=Income inequality Method=DOLS Diagnostics: R^2=0.850496			
Independent variable	**Coefficient**	***t*-sat**	**Probability**
GINI	0.093341	2.829523	0.0142*
POV	−0.008594	−0.955033	0.3570
POPG	2.889689	2.201680	0.0464*
UNMPR	−0.052672	−2.155823	0.0504*
CADIOX	2.471865	3.672075	0.0028*
LOG (RGDPpc)	1.896167	3.417267	0.0046*
C	16.07390	5.325664	0.0001

*Source: Author's computation, **Significant at 5% and 10% level respectively. DOLS: Dynamic ordinary least square, GINI: Gini Index a measure of income inequality, POV: National poverty level captured by headcount, UNMPR: Unemployment rate, POPG: Population growth rate, RGDPpc: Real Gross Domestic product per capita, CADIOX: Consumption of coal in a thousand short tons

between temperature square (TSQ) and income (GINI). This tends to confirm the existence of the non-linear relationship between climate change and income inequality which showed a U-shaped relationship. Climate change is found to substantially impact GINI in Nigeria at a 5% level of significance. One unit increase in T initially reduces GINI by 1279 units and later increases inequality by 23 units. This outcome conforms with the studies of Alam et al. (2017), Dasgupta et al. (2020), and Sam et al. (2021).

In line with expectations, poverty was found to have a positive substantial impact on GINI. A 1% increment in poverty leads to a 37% increase in income inequality. As revealed by Ogbeide-Osaretin et al. (2016), poverty widens the income inequality gap. As the poor do not often have access to quality and higher levels of education which will create room for employment or increase their income-earning ability. The cycle continues, and the inequality gap widens unless it is broken by effective government policies such as increasing the welfare of the poor (increased access to education and health). However, contrary to expectation, the unemployment rate (UNMPR) was found to have a negative relationship with GINI which was however not significant. The results revealed that an increase in unemployment reduced income inequality. Nevertheless, the unemployment rate in Nigeria is more under-employment, and in most cases, the recorded data often underestimates the unemployment rate in Nigeria.

Figure 2: Trends of inequality and poverty



Source: Authors' chart

The result also divulged that population growth and household size were found to have a positive relationship with GINI as expected which was however insignificant. The result revealed a 1% increase in population growth by 19% in GINI in Nigeria. This upshot is in agreement with the outcome of Onwuka (2006), and Ogbeide-Osaretin and Orehwereh (2020) who found that population is harmful to development and will increase the income gap.

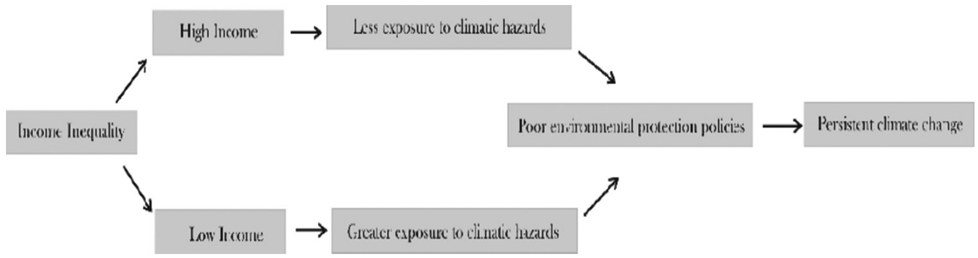
4.5.2. Estimation of the climate change model

Following the outcome of the cointegration test which confirmed the existence of cointegration among the variables, the DOLS was employed in the estimation of the model

The upshot of the DOLS estimation as presented in Table 5 revealed that in conformity to expectation, income inequality had a substantial positive impact on climate change (T). A 1 unit increase in GINI leads to a 0.09 increase in temperature. This is in line with some studies (Yameogo and Dauda, 2020; Hundie, 2021). On the other hand, it was found by some other studies by Kusumawardani and Dewi (2020) that GINI has a negative relationship and impact on climate change. Contrary to our expectations, poverty and unemployment were found to have a negative relationship with climate change. While poverty had an insignificant impact on climate change, unemployment was found to have a significant impact on climate change. This is also contrary to the findings of Yameogo and Dauda (2020) who found that poverty increases climate change. The result further revealed that following some other studies, (Hundie, 2021), population growth was found to have a substantial positive impact on climate change. Population growth was also found to have the highest magnitude in terms of its impact on climate change. However, it is expected that population growth reduces the consumption of energy and the efficiency in the use of energy. Hence, the release of greenhouse gasses will increase climate change and temperature will reduce.

Other important contributors to climate change are the emission of CO_2 and the level of development. The result revealed that these had substantial positive impacts on climate change at a 5% level of significance in agreement with our expectations. 1 unit increase in CADIOX and RGDPpc results in the 2.471865 and 1.89616 unit increases in temperature in Nigeria respectively. This is in line with the findings of Kusumawardani and Dewi (2020) and Hundie (2021).

Figure 3: The climate change income inequality flow



Source: Adopted from Islam and Winkel (2017)

5. POLICY RECOMMENDATIONS AND CONCLUSION

5.1. Policy Implications

The connectivity between climate change and income inequality was examined to determine if there is a feedback relationship between them. Time series annual data was employed where climate change was measured by temperature and income inequality by GINI. Based on the empirical estimates, the following policy colloraries were drawn and recommendations made:

1. Temperature was found to have a negative substantial impact on GINI while temperature square had a positive substantial impact on GINI. This implication of the above is that at the initial level of temperature, income inequality falls as everyone tends to be on the same level with the effect of temperature as a result of climate change. However, as temperature increases with the increases in climate change, the poor not being able to afford means of reducing the effect and are exposed more to climate change, and their sources of income are also affected thereby increasing the income inequality gap. This study thus advocates for control measures for reducing climate change such as reduction of greenhouse gas emissions and putting in place emission fees.
2. Income inequality was also found to have a positive significant impact on climate change. This reveals that the increase in income gap will lead to an increase in activities that are harmful to the environment thereby increasing climate change. Therefore, we advocate for the reduction of income inequality through a transfer of income from the rich to the poor is effective in reducing energy inequality. Also, there is the need to, provide access to commercialized energy to households, increase access to education by the low-income group, and the availability of efficient energy infrastructures to reduce income inequality which will lead to effective climate change adaptation.
3. Poverty was found to have a positive substantial impact on income inequality. Thus, as poverty increases, the gap between the poor and the rich increases. We, thus, counsel for the reduction in poverty through the provision of employment, and an increase in access to education and health.
4. As divulged by the result, population growth negatively and significantly impacts climate change. Hence, we recommend the zealous pursuit of a population growth reduction policy. This can be done by employing practically fertility reduction and birth control.
5. The emission of carbon dioxide substantially impacts climate change. As the emission of CO_2 increases, the rate of climate change increases which is often seen with the increase in temperature and rainfall. We, therefore, advocate for the use of efficient sources and modern energy. This will help to mitigate climate change and hence.
6. Development captured by real GDP per capita was revealed to have a positive substantial impact on climate change. As the quest for development increases, industrialization and household usage of energy increase which is a significant contributor to climate change. Hence, this current study counsels that policy measures for modern sources of energy should be pursued.

5.2. Conclusion

Climate change and income inequality are current priorities for the achievement of sustainable development. While there is a current pursuit of development by developing countries, which have increased economic growth and national income through advancements in technology, the increase in income has not been evenly distributed. Therefore, the objective of this study is to investigate the interaction between climate change and income inequality. The upshot of the result revealed that there is a significant feedback impact between climate change and income inequality in Nigeria. The impact of climate change on income inequality shows a U-shaped hypothesis. Other contributors to climate change were population growth, economic development, and the emission of carbon dioxide. Effective population control and reduction of income inequality through the provision of employment and education are pertinently recommended. Also, efficient and modern energy uses in the purse of development are strongly recommended to reduce climate change and reduction of income inequality.

We however suggest that further studies be cried out to investigate the dynamic feedback connectivity between income inequality and climate change. Inequality ad climate change is expected to have a spillover effect from previous years. Hence, the spillover effect can influence the linkage between them inequality.

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APPENDIX

Table A1: Autoregressive distributed lag model bounds test for income inequality equation

ARDL bounds test Date: 04/29/22 Time: 01:14 Sample: 1981 2020 Included observations: 40 Null Hypothesis: No long-run relationships exist		
Test statistic	Value	k
F-statistic	2.717687	5
Critical value bounds		
Significance (%)	I0 Bound	I1 Bound
10	2.26	3.35
5	2.62	3.79
2.5	2.96	4.18
1	3.41	4.68

ARDL: Autoregressive distributed lag model

Table A2: Autoregressive distributed lag model bounds test for climate change equation

ARDL bounds test Date: 04/29/22 Time: 01:03 Sample: 1981 2020 Included observations: 40 Null hypothesis: No long-run relationships exist		
Test statistic	Value	k
F-statistic	2.661207	6
Critical value bounds		
Significance (%)	I0 bound	I1 bound
10	2.12	3.23
5	2.45	3.61
2.5	2.75	3.99
1	3.15	4.43

ARDL: Autoregressive distributed lag model