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Population Dynamics and Climate Change in Africa: Evidence from Panel Threshold Regression

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ABSTRACT

Climate change has been mentioned as the crucial international threat in recent years. The analysis of population dynamics and climate change is not a straightforward phenomenon to examine. This study investigates the threshold effect of population dynamics and climate change in 44 African countries. Empirically, this study measures population dynamics using total population, urban population and rural population on climate change. The paper initially tested the variables for unit root testing, and it was discovered that the findings demonstrate that the variables are integrated in both order I(1) and I(0). After, the paper confirmed that there is cointegration linking population dynamics and climate change. The findings of the paper further demonstrated that the effect of population dynamics when using renewable energy as the threshold variable has a nonlinear effect on climate change. African countries must consider managing fast-growing urban populations to lower their destructive impact on climate change. This can be achieved by enhancing the living standards of the rural population to avoid their migration to urban areas.

INTRODUCTION

The biggest issue currently facing the African continent is structural issues, and the Sustainable Development Goals (SDG) framework must attend to these structural concerns head-on. One of the fundamental issues of the SDG goals is addressing climate change. According to Dietz et al. (2000), "climate change involves both shifts in long-term averages and increased variation around them, with extreme events becoming more common". Climate change poses a noteworthy hazard to African countries. Already, extreme climate effects in Africa, from the damaging floods, are forcing people to migrate to survive. While Africa is the continent with the lowest emissions, it faces systemic risks that pose significant challenges to its economy and ultimately lead to a decline in modest development gains. Adom (2024) indicated that there are effects of climate change on socioeconomic factors. His work further identified variables such as GDP per capita (considered as income), agricultural productivity, undernourishment, water resources, health, poverty, and energy security. People living in poverty experience the worst effects of climate change, even though they are least responsible for emissions. Climate change has already begun to undermine and reverse development gains while amplifying gender inequality and increasing social and economic injustice around the world in recent years. Climate change has had a devastating impact on millions of people across the globe.

Recent research has shown that there is a possible link between population and climate change. It can be noted that with an increase in population and consumption, greenhouse gases associated with climate change are released more frequently. Therefore, climate change is causing resources to become scarcer as population growth continues at higher rates. It is imperative to acknowledge two separate conditions in which population dynamics and climate change can be associated. The literature has identified climate mitigation and adaptation. Climate mitigation strategies involve reducing emissions from human activities to mitigate climate damage in the long run. At the same time, adaptation refers to lowering susceptibility to the hostile effects of climate change. Stephenson et al. (2010) claim that "humans are causing climate change" often emphasizes that climate change, as it is currently progressing, is man-made rather than a natural phenomenon. This notion believes that existing developments on climate change are more influenced by human activity than nature itself. They further indicated that the main cause of climate change is extensive consumption, which is high in emerging economies, despite slow population growth. It is better to claim that consumers cause climate change than to say humans. There is a huge distinction in carbon emissions between high-income people in developed countries with low population growth and low-income people in developing economies with high population growth. This is to conclude that climate change is determined by consumer behaviour rather than purely by population growth.

Reports indicate that climate change is most likely to affect 17 out of 20 countries. UNECA (2023) projects that West and North Africa are particularly exposed to a temperature increase of 1.5°C and above 3°C. Additionally, the continent has the highest population growth rate in the world and is expected to remain at the top of the rankings due to high fertility rates. In 2009, the population of Africa was anticipated to be 1 billion, and in 2050, the population is estimated to be between 1.9 to 2.5 billion. Furthermore, it is expected that most African population will be residing in urban areas by 2035 and about 60% by 2050 (Guengant & May 2013). In considering the fast population growth and projection in Africa, this figure makes an interesting case to investigate the role of population dynamics on climate change. The current investigation contributes to empirical literature in the following manner: it provides a fresh perspective from 44 sampled African countries by examining the effects of population dynamics on climate change. This approach is different from the work of Dimnwobi et al. (2021), Ssali et al. (2018). These previous studies only used a small sample of African countries. Therefore, this approach might suppress the robustness of a bigger sample to have inclusive results. Following, the study uses the panel threshold regression developed by Seo & Shin (2016) for 44 sampled African economies. This method is powerful because it overcomes the limitation of linear models, which assume that a monotone change in the explanatory variable leads to a monotone result on climate change. The current paper assumes a change in the behavior of the model after passing a certain threshold value, which makes a panel threshold model a suitable tool. Finally, the paper is unlike former papers in a view that it applies a different proxy to population dynamics, such as total population, urban population and rural population as an alternative of using total population as a population dynamic measure only. The selection of such variables is grounded on the justification that the urban population tends to demand more energy compared to the rural population, and this analysis might provide a more comprehensive view of population dynamics on climate change.

Therefore, the commitment of this work was to consider the panel threshold influence of population dynamics on climate change in 44 African countries. The study, therefore, intends to respond to subsequent research questions: (1) Is there a long connection concerning population dynamics and climate change in Africa? (2) What is the threshold effect of population dynamics on climate change? To answer the above questions, the paper applied empirical models such as Pedroni cointegration and panel threshold regression. Therefore, this research is prepared as follows. Part 2 details a review of past studies. The methodology of the paper is presented in Section 3. Part 4 presents the result, and Section 5 is the conclusion of the paper.

LITERATURE REVIEW

According to Jolly (1994) indicated that many contemporary popular works on population and environment adopt neo-Malthusian and naturalistic approaches. The environment is said to deteriorate when a growing population puts weight on already present fixed resources that help uphold or improve the standard of living. As a result, the environment is being put under growing pressure from the population. Contrary to the Malthusian view, according to Simon (1981), a growing population will eventually spur economic growth. Demand rises in response to an increase in the number of consumers brought about by population growth. To meet the demand, this will encourage producers to grow and make use of cutting-edge technologies. The general level of life will increase. More people equal more intelligent people, which boosts economic innovation.

Liddle (2014) conducted a review of cross-country and macro-level studies to examine the relation between population dynamics and environment. In his review, he found that the average household size has an indirect relation with carbon emissions. In comparison, urbanisation has a positively associated with carbon emissions. The study by Menz & Welsch (2012) examined the nexus concerning carbon emissions and demographic differences in OECD economies. Applying panel analysis, it was established that carbon emissions upsurge as the percentage of the elderly and those born after 1960 increases. Therefore, it can be concluded that as population subgroups rise in the future, demographic changes are likely to increase gas emissions. The paper by Dalton et al. (2008) assesses the probable impacts of population aging on energy use and carbon emissions in the United States. The study found that almost 40% exhibit that an aging population lowers long-term carbon emissions. Zagheni (2011) studied the influence of margins in population age structure on carbon emissions in the USA. The paper established that per-capita emissions rise with age until an individual is around 60 years old. Then, per-capita emissions lean to decrease. The review above shows studies in the USA by Dalton et al. (2008) and Zagheni (2011) share the same view that an aging population has a negative impact on carbon emissions.

Abdelfattah et al. (2018) study is concerned about the Arab countries' population and environment regarding climate change connections. The outcomes of the study demonstrated that the population has a direct, meaningful role in carbon emissions in the long and short run. The work of Rehman & Rehman (2022) explored the role of economic variables on the environment by assessing 5 five popular Asian countries, such as Indonesia, Pakistan, Bangladesh and China, and India. The paper applied annual data from 2001 to 2014 with an application of grey relational analysis. The paper revealed that rapid population change has a direct influence on environmental damage. The study of Zhu & Peng (2012) assessed the effect of population size, population structure, and consumption level on gas emissions in China. Results reveal that changes in population structure and Urbanization were the main effects on climate change. The work of Guo et al. (2023) investigated the effect of aging on carbon emissions across the various phases of regional development. The paper used a STIRPAT model grounded on a balanced provincial panel of China data from 1995 to 2019. The finding revealed that there exists of an inverted U-shaped connection between an aging population and emissions. The study by Wu et al. (2021) empirically studied the influence of population flow and other associated variables on China's carbon emissions. The paper applied two approaches of analysis, which are panel regression and heterogeneity examination with the fixed effect model. The study found that population flow also has a negative impact on carbon emissions. At the same time, urbanisation has no meaningful correlation with carbon emissions. In addition, GDP per capita bears a direct cause on carbon emissions. The work of Yeh & Liao (2017) analysed how population and economic growth influence emissions in Taiwan. The paper used a STIRPAT model for the period 1990 to 2014. The findings of the paper were that there is a direct connection concerning population and carbon emissions in Taiwan. Whereas the study further demonstrates an indirect role of GDP per capita on emissions.

By applying time series data in Indian Sikdar & Mukhopadhyay (2016) modelled the influence of population change on carbon emissions. The study applied a STIRPAT modelling framework for the period 1980-2012. The study found that the household size and GDP per capita are fundamental variables in accelerating carbon emissions in India. The paper by Zhao et al. (2021) studied the link of population development factors on carbon climate change in China. The paper applied a ridge regression within the framework of the STIRPAT model for 30 provinces. The study found that the total population has an influence on carbon emissions in all the provinces. The work of Anser (2019) was to discover the significant contributing factors of greenhouse emissions in Pakistan. The study explored human activities on the quality of the environment by using ARDL on the period 1972 to 2015. The results show that population growth and urbanisation are contributing aspects of higher emissions in the long run. The above review was concern with Asian countries' studies. It is clear from the reviews that China has conducted more studies regarding the relationship between population and climate change. The studies by Guo et al. (2023) and Zhao et al. (2021) have commonly applied the same model of STRIPAT for their analysis. Their studies have both confirmed the significance of population on carbon emissions. Furthermore, in the above review was generally observed that the STRIPAT model framework was used in other economies such as Taiwan, India and Pakistan.

The association between population dynamics and climate change was also investigated in African countries. These studies consist of country-specific studies such as Sulaiman and Abdul-Rahim (2018) and Chekouri et al. (2020). An assessment of Sulaiman and Abdul-Rahim (2018) examined the influence of population growth and controlling for energy consumption and economic growth on carbon emissions in Nigeria. The article applied the autoregressive distributed lag (ARDL) for the period 1970 to 2010. The paper found that economic growth has a direct influence on gas emissions. At the same time, population was observed to be irrelevant in rationalizing emissions. The study by Chekouri et al. (2020) researched the influence of population and other variables on carbon emissions in Algeria. The paper applied time series techniques for data spanning from 1971 to 2016. The study confirms that the population contributes positively to carbon dioxide emissions in Algeria. The literature also consists of cross-country studies in Africa.

The paper by Dimnwobi et al. (2021) scrutinized the relationship between population dynamics and environmental degradation in Africa. The paper sampled 5 countries of Africa, which are the DR Congo, Ethiopia, Nigeria, South Africa, and Tanzania, for the period 1990 to 2019. The paper indicated that both GDP per capita and age population structure have a direct influence on climate change. The study by Ssali et al. (2018) investigated the effect of Population change in relation to emissions by also considering energy and economic growth in Sub-Saharan African economies. The paper sampled 6 African countries for the period 1990 to 2014, which are Kenya, Nigeria, Botswana, Benin, Togo and Mauritius. The paper revealed that a 1% rise in population will lead to carbon emissions increasing by 0.22%. The work of Tripathi & Syed (2018) investigated the nexus between population dynamics and climate change among the sampled developing countries. To analyse the association concerning population cohort and gas emissions in 17 developing economies, a panel data set was constructed for the period 1980 to 2014. The findings of the study show that population and GDP have a direct link with greenhouse gas emissions. The study Adusah-Poku (2016) used a panel data set of 45 SSA economies from 1990-2010. The paper determined that a rise in both urbanisation and population increases environmental damage. The research by Asane-Otoo (2015) investigated the determinants of carbon emissions in Africa. The paper used annual data from 1980 to 2019 with a sample of 45 unbalanced African countries. The outcomes show that per capita income has a direct, meaningful impact on both low- and middle-income African countries. Also, the effect of urbanization and population indicates an insignificant effect across income groups. The work by Saka (2014) studied the connection between population growth and carbon emissions in Africa. The paper applied an unbalanced data set of 52 African economies for the period 1960 to 2012 using the STIRPAT framework. The paper findings suggested that a 1% upsurge in population growth will increase carbon emissions.

From the above literature, especially studies conducted in Africa. There is clear evidence that there is a positive effect of population on carbon emissions. This finding implies that as the population is increasing, this puts pressure on demand for goods, which ultimately exacerbates environmental degradation. However, there are still some holes in the presented literature, as the studies fail to provide evidence on how the population from rural and urban areas reacts to climate change. It is only a few studies that considered the role of urbanisation, such as Asane-Otoo (2015) and Adusah-Poku (2016), but lack in showing both the urban and rural population effects on climate change. Also, there is a lack of existing studies to moderate the net immigration population in the literature, which the current study will consider. Lastly, the previous studies only applied linear models to analyse the relationship between population dynamics and climate change; therefore, the current study intends to use nonlinear models to investigate the phenomena.

MATERIALS AND METHODS

Model Building

To probe the association between population dynamics and climate change in selected African economies, the following panel econometric framework is first built to examine the phenomena.

$$LCCO_{it} = \beta_i + \alpha_1 LREC_{it} + \alpha_2 LAPOP_{it} + \alpha_3 LUPOP_{it}$$
$$+\alpha_4 LRPOP_{it} + \alpha_5 LGDPP_{it} + \alpha_6 LNETM_{it} + \theta_{it} \quad \ldots(1)$$

Where *i* represent the selected African countries, *t* represents the year 2004 to 2022. $LCCO_{it}$ is the climate change variable for each African country, $LREC_{it}$ represent the consumption of renewable energy, $LGDPP_{it}$ is gross domestic product per capita. $LNETM_{it}$ is the net immigration in African countries, $LAPOP_{it}$ represent the total population, $LUPOP_{it}$ is the urban population and $LRPOP_{it}$ is the rural population. q_{it} is a random disturbance term, b_i and a_i is the intercept and parameter estimates. Gross domestic product per capita ($LGDPP_{it}$) has also been highly linked to environmental quality, with higher levels of pollution at lower income levels and better environmental quality at higher income levels.

Migration ($LNETM_{it}$) directly affects economic growth through increased productivity and labor force, all of which speed up the economic growth process. The economic growth process may then serve as the indirect channel through which migration can affect climate (Olanipekun 2025). Therefore, Net migration is expected to have a positive correlation with environmental decline. In reducing environmental harm, enhancing energy security, and encouraging innovation in clean energy technologies, renewable energy ($LREC_{it}$) supports sustainable climate change development (Achuo et al. 2022). Therefore, there is an expected negative relationship between renewable energy and the climate environment.

Therefore, the interest of this investigation is to study the nonlinear association between population dynamics and climate change. The paper adopts the threshold regression by Seo & Shin (2016), and the analyses are computed using the Stata code developed by Seo et al. (2019). The motivation to adopt the threshold regression is that the method accounts for endogeneity and simultaneous issues common in panel data modelling (Bolarinwa & Akinlo 2021). In expressing the above equation, the paper contextualizes the function as follows:

$$LCCO_{it} = \alpha_1^1 LREC_{it} + \alpha_2^1 LAPOP_{it} + \alpha_3^1 LUPOP_{it} + \alpha_4^1 LRPOP_{it} + \alpha_5^1 LRPOP_{it} + \alpha_6^1 LNETM_{it} + \theta_{it} \; if \; q_{it} \leq \gamma$$
$$\alpha_1^2 LREC_{it} + \alpha_2^2 LAPOP_{it} + \alpha_2^2 LUPOP_{it} + \alpha_4^2 LRPOP_{it} + \alpha_5^2 LRPOP_{it} + \alpha_6^2 LNETM_{it} + \theta_{it} \; if \; q_{it} > \gamma \quad \ldots(2)$$

The above function (2) represents equation (1) as the threshold regression. Where all other variables have already been explained. Here q_{it} is the threshold variable. In the interest of this paper, the threshold variables will be rotated among population dynamics variables such as total population, net immigration, rural population, and urban population for sensible results.

Data Source and Description

This study consists of 44 Selected African countries, and the span of the study is between 2004 to 2022. The choice of these economies and the data span was chosen based on the convenience of data sources. The sample countries are Algeria, Angola, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Congo, Dem. Rep, Congo, Rep, Cote d'Ivoire, Egypt, Arab Rep, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guatemala, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Nigeria, Niger, Rwanda, Senegal, Somalia, South Africa, Tanzania, Togo, Tunisia, Uganda, Zambia, and Zimbabwe. All the data is sourced from World Development Indicators (WDI) online. Where LCCO is climate change measured by CO_2 emissions (kt), LREC is the Renewable energy consumption (% of total final energy consumption), LGDPP is the GDP per capita (constant 2015 US$), LAPOP is the population, total in millions, LRPOP is the rural population (% of total population), and LUPOP is the urban population (% of total population).

Preliminary Tests

Before estimating equation (2), the study will first explore the moments of the data employed. Initially, the paper will apply the descriptive results involving the mean, median, maximum, and standard deviation of the data. Following that, we will employ correlation relations among the variables. The correlation scrutiny intends to determine if there is ever a high correlation among independent variables, which will give a sign of the presence of multicollinearity. Furthermore, the paper will assess whether cross-sectional dependency is present in the panel. The purpose of such a test is to ensure that the parameters estimated are consistent in the absence of cross-sectional dependence. The paper will apply the test of Pesaran (2004), Friedman (1937), and Frees (2004) to test for cross dependence in the panel. Lastly, before the main estimation, the study will apply the panel unit root testing with the use of ADF-Fisher Chi-square and PP-Fisher Chi-square.

Table 1: Descriptive results for African countries.

Variable	Mean	Std. dev.	Min	Max
LCCO	-0.967	1.375	-3.826	2.133
LREC	3.870	1.104	-2.813	4.583
LAPOP	16.285	1.323	13.095	19.202
LRPOP	4.002	0.364	2.226	4.509
LUPOP	3.644	0.463	2.212	4.507
LNETM	-4.106	8.799	-13.671	13.377
LGDPP	7.187	0.901	5.569	9.302

RESULTS AND DISCUSSION

For empirical results, the paper first starts by understanding the moments of the data used. Firstly, we observe the descriptive results, followed by correlation analysis, and followed by the main estimation results for the sample employed.

Table 1 presents the descriptive results of 44 Selected African countries. The table only presents the mean, std dev, minimum and maximum value. It can be observed that, on average total population has the highest with 16.28, and climate change measured with LCCO is 0.96 is the lowest on average. The results show that based std. Dev net immigration shows the highest volatility, followed by climate change and total population.

Table 2: Panel correlation results.

	LCCO	LREC	LAPOP	LRPOP	LUPOP	LNETM	LGDPP
LCCO	1.0000						
LREC	-0.647	1.0000					
LAPOP	-0.183	-0.0566	1.0000				
LRPOP	-0.649	0.4074	0.2009	1.0000			
LUPOP	0.655	-0.4183	-0.1480	-0.8711	1.0000		
LNETM	0.019	0.0973	0.0922	-0.1723	0.0701	1.0000	
LGDPP	0.9201	-0.5638	-0.1879	-0.6519	0.6380	0.0554	1.0000

Table 3: Cross dependency test results.

Cross-section test	Test statistics	p-value
Pesaran's test of cross-sectional independence	3.635	0.0003
Friedman's test of cross-sectional independence	41.195	0.5498
Frees' test of cross-sectional independence	5.432	0.2601

The paper also presents results for correlation analysis in Table 2. The purpose of these results is to report on the basic association between the variables and to determine the multicollinearity among the independent variables. It can be observed that between the dependent variable (LCCO) and the independent variables, there are different associations. It can be witnessed that renewable energy consumption, total population, and rural population have a negative association with climate change. On the other hand, urban population, net immigration, and GDP per capita have a positive association with climate change. Finally, it can be concluded regarding the association among independent variables that there is no strong association with a coefficient of around 0.9, which can demonstrate the potential of multicollinearity among independent variables. This concludes that the independent specification is free from multicollinearity.

Large evidence of the panel literature proves that panel data series are prospectively to demonstrating strong cross-sectional dependence, which may occur due to the existence of collective shocks. Therefore, the current paper applies three types of panel cross-sectional tests, which are the Pesaran test, Friedman test, and Frees test. As can be witnessed from Table 3, the Friedman and Frees test strongly supports the null hypothesis of no cross-sectional dependence at least at the 1% level of significance.

Table 4: ADF-Fisher Chi-square Panel unit root results.

	Levels	First difference
LCCO	91.6257 (0.3746)	413.947 (0.0000)***
LREC	85.8629 (0.5446)	421.926 (0.0000)***
LAPOP	212.791 (0.0000)***	91.7329 (0.3716)
LRPOP	54.0744 (0.9954)	306.599 (0.0000)***
LUPOP	943.561 (0.0000)***	216.787 (0.0000)***
LNETM	149.899 (0.0000)***	418.652 (0.0000)***
LGDPP	148.149 (0.0001)***	332.392 (0.0000)***

Table 5: PP-Fisher Chi-square Panel unit root results.

	Levels	First difference
LCCO	99.7082 (0.1851)	520.381 (0.0000)***
LREC	156.005 (0.0000)***	575.501 (0.0000)***
LAPOP	876.213 (0.0000)***	68.9622 (0.9335)
LRPOP	38.0575 (1.0000)	495.656 (0.0000)***
LUPOP	3367.88 (0.0000)***	177.286 (0.0000)***
LNETM	170.477 (0.0000)***	1000.47 (0.0000)***
LGDPP	355.104 (0.0000)***	428.153 (0.0000)***

This paper used two tests to investigate the panel unit root among the variables at hand. Table 4 reports the results for the ADF panel unit root, and Table 5 reports the PP Fisher test. Table 4 indicates that most of the variables are stationary at levels except variables LCCO, LREC and LRPOP, which are stationary at first difference. Table 5 indicates that most of the variables are stationary at levels except variable LCCO and LRPOP, which are stationary at the first difference. Therefore, unit root results imply that according to the ADF and PP-Fisher test, all the variables are integrated of order one and zero. Following it will be necessary for the study to ascertain itself with cointegration among the variables. Therefore, this paper applies the Kao panel cointegration developed by Pedroni (2004).

It can be confirmed in Table 6 that there is cointegration. This result implies that population variables and climate change move together in the long run for 44 selected African countries. Following, the paper explores the threshold regression to determine the parameter estimates between population dynamics and climate change.

The empirical findings are reported in Table 7, from columns 2 to 3, reporting the parameters and p-values from threshold regression showing the relationship between population dynamics and climate change in African countries. The paper used renewable energy as the threshold variable, and the choice was arbitrary to sensitize the results. From the results threshold variable has the value of 4.31% to separate the lower and upper regimes for climate

Table 6: Pedroni panel cointegration.

	Statistic	p-value
Modified Phillips–Perron t	7.832	0.000 ***
Phillips–Perron t	-6.311	0.000 ***
Augmented Dickey–Fuller t	-6.887	0.000 ***

Table 7: Static threshold regression results of the study.

	Coefficient	P-value
LOWER REGIME		
LAPOP	-2.116	0.000***
LRPOP	-4.102	0.006***
LUPOP	-0.649	0.647
LNETM	-0.005	0.000***
LGDPP	0.844	0.000***
UPPER REGIME		
CONS	-48.981	0.000***
LAPOP	1.576	0.000***
LRPOP	3.884	0.011**
LUPOP	3.353	0.000***
LNETM	0.007	0.000***
LGDPP	-0.793	0.000***
threshold	4.3188	0.000***

change in African countries. The paper shows that the total population has an indirect role in climate change below the threshold and has a positive effect on the upper regime. These findings imply that the total population in African countries is a contributing factor to climate change in the upper regime. This may suggest that as the total population is increasing, they may demand more goods that also demand more energy, and this ultimately leads to deterioration of the environment when renewable energy is above 4.31%. These results are consistent with the theory of Malthus and the study by Adusah-Poku (2016) on population growth and the environment. The outcome shows that the rural population depicts a nonlinear, meaningful role in climate change in both regimes. The results suggest that when the threshold is below 4.31%, the effect of rural population on climate change is negative, with a coefficient of 4.10, and is significant. However, above the threshold has a positive effect.

The outcome indicates that above the threshold urban population has a positive influence on climate change. These findings suggest that as the urban population is increasing, this has led to an increase in climate deterioration. These might imply that the urban population in African countries their energy demand accelerates more than applying friendly activities to the environment. These results are consistent with the study by Helbling & Meierrieks (2023). The findings on net immigration in African countries demonstrate a nonlinear behavior in climate change. The effect on the upper regime shows a small positive magnitude effect of net migration on climate change. Given that the upper regime results of the impacts of immigration show an increase in climate change, this could push countries over the identified threshold, through migration, to marginally increase climate change problems. If the net immigration to African countries is increasing above the threshold, this will cause an increase in demand for energy due to increased population due to migration. Therefore, this will ultimately deteriorate the environment through increased resource chasing. These results are consistent with the study by Olanipekun (2025). The results on GDP per capita show a negative effect and a positive impact on climate change. This proposes that the relationship between GDP per capita has an inverted U-shape. This suggests that African countries below the threshold have a positive result on climate and is statistically significant. Then, above the threshold, it shows a negative effect. This may suggest that African countries are slowly transitioning into production methods that are environmentally friendly. These results follow the theory of the environmental Kuznets curve (EKC), which suggests that GDP has an inverted U-shape with emissions, and the paper by Mosikari & Eita (2020).

Robustness Check Analysis

This section provides the robustness of the results. The findings of fully modified ordinary least squares (FMOLS) panel regression are presented in Table 8. The technique of FMOLS was developed by Phillips & Hansen (1990). The estimator is preferred in the literature because it assumes the existence of cointegration in the long run. It can be observed that model (1) was estimated with a variation of equations. The parameters of population in total and urban population exert a positive effect on climate degradation, and in both terms of population flows in models 1a and 1c. The two surpassed the significance level at 1%. These results suggest that the total and urban population inhibits the increase of carbon emissions in African countries. The results show that the rural population has a negative effect on climate change.

Table 8: FMOLS regression results.

	Model 1a	Model 1b	Model 1c
LAPOP	0.434 (0.000) ***		
LRPOP		-0.239 (0.084) *	
LUPOP			0.996 (0.000) ***
LNETM	0.0021 (0.087) *	0.001 (0.419)	0.002 (0.104)
LGDPP	0.501 (0.000) ***	0.656 (0.000) ***	0.492 (0.000) ***
LREC	-0.294 (0.000) ***	-0.351 (0.000) ***	-0.233 (0.000) ***
Adjusted R-squared	0.988	0.987	0.989

These findings may suggest that the rural population in African countries demands less of intensive energy sources that are fossil in nature.

Most of the population in rural areas in Africa does not have access to much electricity or other energy sources, which are detrimental to the environment. The coefficient of net migration shows a positive but weak effect on climate change degradation. This may suggest that intra-movement within the African continent is not really a concern for accelerating climate change concerns. The effect of GDP per capita shows a positive effect on climate change degradation. These findings are consistent with many studies, such as Ssali et al. (2018). The coefficient of renewable energy shows that in all models, it has a negative effect on climate change degradation. This may suggest that as African countries invest more in renewable energy sources such as solar, batteries, and hydroelectricity, this may help to alleviate detrimental effects to the climate and achieve sustainability for the environment. These results are like the work of Achuo et al. (2022).

CONCLUSIONS

The current paper investigated the connection between population dynamics and climate change in 44 African economies. The paper was mainly concerned with answering two questions: (1) Is there a long connection linking population dynamics and climate change in Africa? (2) Is the threshold effect of population dynamics on climate change? In relation to the first research question, the analysis established that there is a long-run equilibrium linking population dynamics and climate change in African countries. Secondly, the study established that there is a threshold effect correlation involving population dynamics and climate change. The non-linear effect between the variables confirms this. This study empirically tested this association by applying threshold regression. The paper used three measures to determine population dynamics, which are total population, rural population, and urban population, on climate change in Africa. The paper allowed renewable energy as the threshold variable for modelling. In using 44 African countries, the results show that population dynamics have a threshold effect on climate change. The results showed that all measures of population dynamics have a nonlinear effect. It was shown that the total population, rural population, and urban population have negative effects in the lower regime and have a positive effect in the upper regime. The study further applied robustness by estimating the FMOLS to understand population dynamics and climate change under different assumptions of the estimator. It was found that all three population dynamics proxies have a significant effect on climate change. It was observed that both the total and urban population have a positive effect on climate change, whereas the rural population has a negative effect.

These results have very interesting implications for policymakers on population dynamics and climate change in Africa. Therefore, the paper recommends policymakers to factor the dynamics of the total population, rural and urban population when conveying the local, regional, and global arrangements with regard to climate change. One of the proposals on the total population effect it can be population control through family planning in African countries to avoid a rapid population that will exceed the available renewable energy a point damage to the environment. Secondly, African countries must consider managing the fast-growing urban population to lower its destructive impact on climate change. This can be achieved by enhancing the living standards in the rural population to avoid their migration to urban areas. Lastly, it is necessary to expand future studies by researching the influence of population age, countries' upper- and lower-income groups on climate change in panel quantile analysis.

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