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THE IMPACT OF CLIMATE CHANGE ON THE ECONOMIES OF AFRICAN COUNTRIES

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ABSTRACT

This study investigates the impact of climate change on economic growth in African countries using panel data from the year 2000–2022. the analysis applies Panel Autoregressive Distributed Lag (Panel ARDL) model with the Pooled Mean Group (PMG) estimator, to capture both short-run and long-run equilibrium relationships between economic growth and key climate-related variables, including carbon dioxide (CO_2) emissions, energy imports, and population growth. Prior to estimation, cross-sectional dependence and panel unit root tests were conducted, which confirmed the suitability of the Panel ARDL approach. The empirical findings indicates that CO_2 emissions and energy imports exert positive and statistically significant impacts on economic growth in the short run, reflecting that the emission and energy-intensive activities temporarily stimulate economic performance in African countries. On the other hand, in the long run, the effects of CO_2 emissions, energy imports, and population growth on economic growth are statistically insignificant, signifying that reliance on these factors does not translate into sustained economic growth over time. The error correction term is negative and highly significant, which implies rapid convergence to long-run stability following short-run shocks. These findings suggest that although climate-related factors may stimulate short-term economic growth, they are insufficient for achieving long-term sustainable growth. The study therefore, emphasizes the need for African countries to transition toward cleaner energy sources, strengthening climate adaptation measures, and promotes productivity enhancing investments to achieve sustainable economic development in African countries.

Keywords: Carbon Dioxide (CO_2) Emissions, Energy Imports, Population Growth

INTRODUCTION

African Countries contribute the least to GHGs emissions (only 4%), but the continent's geographic fragility, livelihood patterns, financial and institutional inadequacies and modest economic development amplify its vulnerability to climate change adversity (UNECA, 2009). Climate change refers to long term shifts in temperature and weather patterns, which can be due to changes in the sun's activity or large volcanic eruptions but primarily driven by human activities like the burning of fossil fuels like coal, oil and gas and also by deforestation and industrial emissions (Kumar et al., 2021). Food availability is determined by physical location and the occurrence of moderate warming (an increase of 1°C to 3°C) in the tropical and dry regions of Africa will adversely affect cereal yields, with maize output likely to fall by 6.9% (Brown & Crawford, 2007; FAO, 2010). Rainfall patterns have changed, with arid and semi-arid regions becoming drier and mid-to-high latitudes getting wetter due to more frequent and heavy spells of rainfall (Sarkar, 2012). Likewise, Africa has seen general increases in its temperature since the industrial era, and its rainfall patterns have become more variable in the last century. Mean annual rainfall has decreased in West Africa since the 1960s, while southern and eastern Africa has become more drought-prone. One-third of Africans now live in drought-prone areas, especially in the Sahel, around the horn of Africa and in southern Africa (PACJA, 2009). The estimates show that 1989 to 2019 was the warmest 30-year period in more than 800 years; the most recent decade, 2010-2019, is the warmest decade in the instrumental record so far (National Academy of Sciences, & The Royal Society, 2020). Climate change is having profound impacts on nearly every aspect of our environment, which make it a serious threat to the environment and to the global economy as well.

This research underscores the necessity for comprehensive climate change adaptation strategies that concentrate on both immediate and long-term challenges, and accordingly employs the Panel Autoregressive Distributed Lag (ARDL) model to examine the short and long-run economic impacts of climate change in African countries

Many researchers have worked in this area; some of the studies are, Lalthapersad-Pillay & Udjo, (2014) in their study employed spreadsheet and exported to SPSS. All programming, including data transformation and statistical analyses, was done in SPSS. They sourced their data from the World Bank (2010) and Food and Agricultural Organization (FAO) (2008) reports. The results of the analysis based on the calculation of an overall index comprising four proxy variables, showed that eleven African countries are high risk countries whose future economic development may be impeded by climate change. Adaptation, economic diversification, mitigation, climate-smart polices within the framework of development policy are pertinent policy options. The authors concluded that Climate change should ideally have been given more attention under Millennium Development Goal 7. Furthermore, Tahtane, (2022) used the cross- augmented autoregressive distributed lag (CS ARDL) and the cross-sectionally augmented distributed lag (CS-DL) Models. The study investigated the effect of climate change on both short and long-run economic growth in Africa using a panel of 34 selected African countries for the period of 1971–2019. Data was sourced from the Economic Activity and Climate Indicators of the International Monetary Fund, except for Rwanda and Burundi for which the Climatic Research Unit database was used instead. The result shows clear evidence that climate change is negatively associated with economic growth in both the short and long-run. The conclusion shows that climate change damages the African economic performance and that is one of African most significant long-term policy challenges, so that keeping climate change at the forefront of government decision agendas will be critical and inevitably. Janssens et al., (2022) used the Global Biosphere Management Model (GLOBIOM), Sourced data from the World Bank Doing Business Survey, covering the period 2000-2020. The authors concluded that to mobilize continental agricultural trade in Africa, different policy measures will not bring substantial benefits on their own but are jointly needed. On the contrary, Yang et al., (2022) used common correlated effect means group (CCEMG), nonlinear Autoregressive Distributed Lags (NARDL) approaches, and asymmetric causality tests from both a country and regional perspective, spanning from 1980 to 2017. The results reveal that energy in total contributes to growth, while nonrenewable energy reduces economic growth across the panel of selected countries. More so, Sarkodie et al., (2022) employed the novel panel estimation techniques capable of solving the complexities of emissions and cross country time series data, used Romano-Wolf correction technique to investigate the multiple hypotheses using the baseline model specification. The result shows that climate change vulnerability presented herein indicates the tendency of economies to experience the negative impacts of climate risks, also increasing level of anthropogenic GHG emissions exacerbate the vulnerability of ecosystem services, typically in sub-Saharan Africa, Eastern and Southern Asia.. Climate change readiness underpins long-term climate change mitigation and impact reduction strategies across global economies. Garuba et al., (2021) assess the change in rainfall trend due the impact of climate change in Samaru, Zaria Kaduna State. Rainfall data from 1981 – 2018 (38 years) were collected from the Nigerian Meteorological Agency (NIMET). The data was analyzed using Excel and XL-Statistics to evaluate the mean, standard deviation and coefficient of variation of monthly and annual rainfall and other statistical parameter. The study revealed that there is a significant change in the trend of annual rainfall as the highest rainfall was recorded in year 1994 with a value of 1487 mm and lowest rainfall in 1999 as 440 mm. Abidoye & Odusola, (2015) used the standard cross-country growth models to estimate the relationship between economic growth and its key determinants. Using annual data for 34 countries from 1961 to 2009, source data from the 2011 Africa Development Indicators (ADI) (World Bank, 2011) and temperature data for each African country were obtained through the Climate Research Unit (CRU) at the University of East Anglia, Norwich, UK. The results show the importance of the initial condition (the log of initial GDP per capita) in the continent growth process. The authors concluded that the vulnerability of the African economy and key sectors driving economic performance (such as agriculture, forestry, energy, tourism, coastal and water resources) to climate change has been acknowledged to be substantial. Adesete et al., (2022) examined the nexus between climate change and food security in Sub-Saharan African Region (SSA). With focus on 30 countries within the region, the study employed the dynamic panel data analysis using the one-step and two-step system generalized method of moments (GMM) model. The time observed spanned from 2000 through 2019. The study found that increase in greenhouse gas emission would lead to an increase in prevalence of malnourishment rate, resulting in a decrease in food security in SSA. Ezeruigbo & Ezeoha, (2023) used the Random Effect Panel Regression Model; data were sourced from both the World Development Report and the data stream of the Primary Health Care Performance Initiative (PHCPI) which involved a panel of 49 African countries covering the period 2000–2019. The result show that countries that have higher government health expenditure levels above the 1.7% regional average and face higher climate change risk may likely record an increase in OPHE, which confirms the overwhelming pressure the former, can have on primary health outcomes. The authors concluded that indeed climate change might have significantly shifted the burden of PHC financing to individuals and households in Africa. Odusola & Abidoye, (2015) examines the impact of temperature and rainfall volatility on economic growth in 46 African countries, data is deduced from the database of Climate Research Unit (CRU), employed the Bayesian hierarchical modeling approach to estimate both country level and Africa-wide impact of climate change and extreme events on economic growth in Africa, results show that a 10 Celsius increase in temperature leads to 1.58 percentage points decline in economic growth while temperature shock reduces economic growth by 3.22 percentage points.. The authors concluded that Africa is at the centerpiece of climate change and it exhibits a good case for climate change paradox – contributes marginally to greenhouse gas emission but bears excruciating impacts with limited capacity to manage them.

From the empirical review, some of the studies provide evidence of long-run climate effects but are mostly cross-regional or multi-country in scope. The previous studies hardly incorporate country-specific institutional and structural characteristics, thereby limiting their policy relevance for individual African economies. Much of the empirical literature concentrates on single outcome variables such as agricultural productivity, food security, or emissions, with limited integration of broader macroeconomic growth frameworks.

To bridge existing gaps, this study exploit comprehensive data from 2000 to 2022 and applies a Panel ARDL model with the Pooled Mean Group estimator to straighten out the short-run and long-run impacts of carbon dioxide emissions, energy imports, and population growth on GDP in African economies.

MATERIALS AND METHODS

Secondary panel data spanning from 2000-2022 for some selected African countries (Algeria, Angola, Benin, Cameroon, Chad, Congo, Dem. Rep., Congo Rep., Cote d'Ivoire, Egypt, Arab Rep., Equatorial Guinea, Gabon, Ghana, Kenya, Niger, Nigeria, Rwanda, Senegal, South Africa, Uganda, Zimbabwe, Zambia.) were used for this study. Panel data was appropriate because it combine time series and cross-sectional observations, allowing for better control of heterogeneity across African countries.

The data used for this study were sourced from World Development Indicators (WDI) database of the World Bank (2025). The variables include Carbon dioxide emissions (CO_2), Energy Imports (EI) and Population Growth (PG) as the independent variables. Gross Domestic Product (GDP) as the dependent variable,

The study adopts the Panel Autoregressive Distributed Lag (Panel ARDL) approach using the Pooled Mean Group (PMG) estimator developed by Pesaran, Shin, and Smith (1999). The Panel ARDL technique is appropriate because it allows for a mixture of variables integrated at level I(0) and first difference I(1), while simultaneously estimating short-run dynamics and long-run equilibrium relationships.

The functional relationship between dependent variable (GDP) and independent variables (CO_2, EI and PG) is expressed as:

$$GDP = f(CO_2, EI, PG) \quad (1)$$

This indicates that economic growth depends on carbon emissions, energy imports, and population growth

The long-run relationship is specified as:

$$GDP_{it} = \alpha_i + \beta_1 CO_{2_{it}} + \beta_2 EI_{it} + \beta_3 PG_{it} + \varepsilon_{it} \quad (2)$$

Where;

GDP_{it}: represents economic growth in country i at time t

α_i : is the country-specific intercept.
$\beta_i and \beta_j$: are the long-run coefficients.
ε_{it} : Error term.
The short-run dynamics and speed of adjustment to long-run equilibrium are captured using the error correction representation:

$$\Delta GDP_{it} = \varphi_i(GDP_{it-1} - \beta_1 CO_{2_{it-1}} - \beta_2 EI_{it-1} - \beta_3 PG_{it-1}) + \sum \lambda_i \Delta GDP_{it-1} + \sum \delta_{1i} \Delta CO_{2,it} + \sum \delta_{2i} \Delta EI_{it} + \sum \delta_{3i} \Delta PG_{it} + \mu_{it} \quad (3)$$

Where;
Δ: denotes first difference
φ_i: is the error correction coefficient indicating the speed of adjustment to long-run equilibrium.
$\lambda_i and \delta_i$: represent short-run coefficients.
μ_{it} : is the error term

RESULTS AND DISCUSSION

Results

This chapter gives the analysis and interpretation of results for this study covering the period 2000–2022. Comprises of descriptive statistics, tests of assumptions, model estimation using the Panel Autoregressive Distributed Lag (Panel ARDL) Pooled Mean Group (PMG) estimator, hypothesis testing, and discussion of findings, conclusion, limitations, and suggestions for future research.

Table 1: Descriptive Statistics for CO_2 Emissions, Energy Imports (EI), GDP Growth, And Population Growth (PG)

	CO2	EI	GDP	PG
Mean	230.6449	-78.75097	3.885879	1.584601
Median	51.65477	16.73858	4.014588	1.468837
Maximum	9937.131	318.37	63.37988	21.70034
Minimum	-89.58432	-3300.147	-28.75858	-10.92744
Std. Dev.	991.5059	292.2236	5.163761	2.008212
Observations	1237	1237	1237	1237

Table 1.1 shows the descriptive statistics for CO_2 emissions, energy imports (EI), GDP growth, and population growth (PG). CO_2 emissions have the highest standard deviation (991.51), indicating large differences in emissions among countries.

Table 2: Cross-Sectionality Test Summary

Variable	Pesaran Statistic	Prob.
GDP	10.86616	<0.05
PG	8.611915	<0.05
CO2	36.75612	<0.05
EI	14.66580	<0.05

Table 3: Stationary Result

Variable	Level	after 1st diff.	Order
GDP	< 0.05	..	I(0)
PG	0.00009	..	I(0)
CO2	1	< 0.05	I(1)
EI	0.3445	< 0.05	I(1)

Test to confirm the presence of cross-sectionality (Table 2.) was carried out on the panel variables to determine which unit root test is best. The result from the test provided sufficient evidence for the use of Pesaran test.
The stationarity test was carried out using Pesaran test to determine the order of integration of each variable. Table 3 shows that GDP and population growth (PG) are stationary at level, I(0), while CO_2 emissions and energy imports (EI) become stationary after first differencing, I(1). The mixture of I(0) and I(1) variables justifies the use of the Panel ARDL estimation technique, which accommodates different integration orders without losing model validity.

Table 4: Correlation Matrix

	CO2	EI	GDP	PG
CO2	1	-0.538937	0.108368	0.430882
EI	-0.538937	1	-0.286667	0.371567
GDP	0.108368	-0.286667	1	0.371567
PG	0.430882	-0.539923	0.0371567	1

The results in Table 4 indicate that carbon dioxide emissions (CO_2) and GDP have a weak positive correlation (r = 0.108368), suggesting that economic growth in some selected African countries is marginally associated with rising emissions. Energy imports (EI) show a weak negative correlation with GDP (r = -0.286667), implying that inefficient energy use may suppress growth. Population growth (PG) shows a weak positive relationship with GDP (r = 0.0371567), indicating that population expansion marginally contributes to economic output in some African nations The correlation coefficients are all below 0.8, indicating no multi-collinearity. Thus, all variables can be included in the same regression model.
The Panel ARDL model was used to estimate both the short-run and long-run relationships between the dependent variable (GDP) and the independent variables (CO_2, EI, and PG).

Table 5: Short-Run Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
COINTEQ01 (ECM)	-0.975208	0.052993	-18.40262	< 0.05
D(CO_2)	0.053296	0.018837	2.829282	0.0050
D(EI)	0.236626	0.157853	1.499028	0.1349
D(PG)	-2.973672	2.378619	-1.250167	0.2122

The results in Table 5 indicate that in the short run, although both CO_2 emission and energy import both have positive effects on GDP growth, only CO_2 emissions is statistically significant (p = 0.05). This suggests that increases in CO_2 emissions stimulate economic activity through industrialization. Population growth, PG, is negative and also statistically insignificant. The error correction term (COINTEQ (-1)) is negative and significant, confirming stability and that short-run deviations from equilibrium are corrected at a speed of 97% each period.

Table 6: Long-Run Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO2	-0.002622	1.11E+09	-2.37E-12	1.0000
EI	0.008452	4.91E+10	1.72E-13	1.0000
PG	-0.115147	5.58E+11	-2.06E-13	1.0000

The long-run results in Table 6 shows that CO_2 emissions, energy intensity, and population growth are all statistically insignificant (p = 1.000). This implies that climate-related variables do not sustain economic growth in the long term. Thus, while short-term economic activities benefit from higher emissions and energy consumption, the long-term effects are neutral or even negative.

Based on the estimation results, the final Panel ARDL model for the study is presented below, capturing both the short-run dynamics and long-run equilibrium relationships between climate change variables and economic growth.

Short-run Error Correction Model:

$$\Delta GDP_{it} = -0.975208\ COINTEQ01_{i,t-1} + 0.053296\Delta CO_{2\ it} + 0.008452\Delta EI_{it} - 0.115147\Delta PG_{it} + \varepsilon_{it} \quad \text{(iv)}$$

Long-run Equation:

$$GDP_{it} = -0.002622 CO_{2\ it} + 0.008452 EI_{it} - 0.115147 PG_{it} + u_{it} \quad \text{(v)}$$

Discussion

The results from the Panel ARDL model (Tables 4.4 & 4.5), show how carbon dioxide emissions (CO_2), energy imports (EI), and population growth (PG) affect economic growth in both the short run and the long run. The error correction term (–0.975208, p = <0.05) is negative and significant, meaning that any short-term imbalance between the variables is quickly corrected indicating stability. In simple terms, the model returns to long-run stability very fast after a shock, confirming that the relationship among the variables is steady over time.

In the short run, although both CO_2 emissions (0.053296, p = 0.005) and energy imports (0.236626, p = 0.1349) have positive effects on economic growth, only CO_2 is significant. This means that when emissions increase, GDP also tends to rise. This finding reflects the experience of some African countries, where industry is a major contributor to short-term economic growth.

Population growth (-2.973672, p = 0.2122) has a negative and statistically insignificant effect on the economic growth in the short run. This implies that an increase in population and energy imports alone do not necessarily lead to higher output unless it is matched with job creation, quality education, and productivity-enhancing investments.

In the long run, the coefficients for CO_2 (–0.002622), EI (0.008452), and PG (–0.115147) are not statistically significant (p = 1.000). This means these variables do not have a lasting impact on GDP over time. The short-run gains from emissions and energy use eventually fade as economies adjust, suggesting that the effects are temporary. This supports the idea that while African countries may grow rapidly through emission-driven activities, such growth is not sustainable in the long-run.

Overall, the findings show that CO_2 emissions boost short-run economic growth, but its long-run effects disappear.

CONCLUSION

This study examined the relationship between economic growth, carbon dioxide emissions, energy imports, and population growth in selected African countries from 2000 to 2022 using the Panel ARDL (PMG) model. The results show that only CO_2 emissions have a significant short-run positive effect on GDP growth, while their long-run effects are statistically insignificant. The error correction term is negative and significant, confirming model stability, showing that short-run deviations are corrected back to long-run equilibrium.

The findings suggest that short-run growth in the selected African countries often relies on industrial activities that increase emissions. However, this form of growth is not sustainable in the long term.

REFERENCES

Abidoye, B. O., & Odusola, A. (2015). Climate Change and Economic Growth in Africa: An Econometric Analysis. *Journal of African Economies*, *24*(2), 277–301. https://doi.org/10.1093/JAE/EJU033

Adesete, A. A., Olanubi, O. E., & Dauda, R. O. S. (2022). Climate change and food security in selected Sub-Saharan African Countries. *Environment, Development and Sustainability*, 1–19. https://doi.org/10.1007/s10668-022-02681-0 Evidence from Ghana and Burkina Faso. *African Security Review*, 17(3), pp. 39-57.

Ezeruigbo, C., & Ezeoha, A. E. (2023). Climate change and the burden of healthcare financing in African households. *African Journal of Primary Health Care & Family Medicine*, *15*(1). https://doi.org/10.4102/phcfm.v15i1.3743

FAO (Food and Agriculture Organisation) (2010). Climate Change Implications for Food Security and Natural Resource Management in Africa. *Twenty-sixth Regional Conference for Africa, Angola,* 3-7 May 2010. Rome: FAO.

Garuba, H. S., Mukhtar, M. K., Ugama, G. N., Jamila, A., Aliyu, M. K., & Yahaya, G. (2022). EVALUATION OF

RAINFALL TRENDS DUE TO CLIMATE CHANGE: A CASE STUDY OF SAMARU, ZARIA. *FUDMA JOURNAL OF SCIENCES*, *5*(4), 205-209.

Janssens, C., Havlik, P., Boere, E., Palazzo, A., Mosnier, A., Leclère, D., Balkovic, J., & Maertens, M. (2022). A sustainable future for Africa through continental free trade and agricultural development. *Nature Food*, *3*(8), 608–618. https://doi.org/10.1038/s43016-022-00572-1

Kumar, V., Ranjan, D., &Verma, K. (2021). Global climate change: the loop between cause and impact. *In Global climate change* (pp. 187-211). Elsevier.

Lalthapersad-Pillay, P., & Udjo, E. O. (2014). The implications of climate change for Africa's economic development. *Journal of Economic and Financial Sciences*, *7*(3), 871–888. https://doi.org/10.4102/JEF.V7I3.245

Odusola, A., & Abidoye, B. O. (2015). Effects of Temperature and Rainfall Shocks on Economic Growth in Africa. *Social Science Research Network*. https://doi.org/10.2139/SSRN.3101790

PACJA (Pan African Climate Justice Alliance). (2009). The Economic Costs of Climate Change in Africa. [Online] Available: *www.christainaid.org.uk/images/economic-cost-of-climate-change-in africa.pdf.* (Accessed 8 January 2012).

Pesaran, M. H., Shin, Y., & Smith, R. J. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association*, 94(446), 621–634.

Sarkar, A.N. (2012). Sustainable development through pathways of mitigation and adaptation to offset adverse climate change impacts. [Online]. Available: *http://link.springer.com/chapter*/10.1007%2F978-3-22266-5_33. (Accessed 20 April 2012).

Sarkodie, S. A., Ahmed, M. Y., & Owusu, P. A. (2022). Global adaptation readiness and income mitigate sectoral climate change vulnerabilities. *Humanities & Social Sciences Communications*, *9*(1). https://doi.org/10.1057/s41599-022-01130-7

Tahtane, M. (2022). The Impact of Climate Change on Economic Growth in Africa*: An Econometric Analysis*. *6*(2), 398–410. https://doi.org/10.58205/fber.v6i2.1325

UNECA (United Nations Commission for Africa), (2009) Economic Report on Africa 2010. [Online] Available: *http://www.uneca.org/publications/economic-report-africa-2010*. (Accessed 29 January 2012).

world bank (2025). *world development indicators* [dataset]

Yang, C.-F., Namahoro, J. P., Wu, Q. S., & Su, H. (2022). Renewable and Non-Renewable Energy Consumption on Economic Growth: Evidence from Asymmetric Analysis across Countries Connected to Eastern Africa Power Pool. *Sustainability*, *14*(24), 16735. https://doi.org/10.3390/su142416735