Cogent Economics & Finance

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/oaef20

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To cite this article: Suleiman O. Mamman, Kazi Sohag & Attahir B. Abubakar (2023) Climate change and inclusive growth in Africa, Cogent Economics & Finance, 11:2, 2282869, DOI: 10.1080/23322039.2023.2282869

To link to this article: https://doi.org/10.1080/23322039.2023.2282869

Published online: 19 Nov 2023.

Mamman et al., *Cogent Economics & Finance* (2023), 11: 2282869
https://doi.org/10.1080/23322039.2023.2282869

cogent economics & finance

DEVELOPMENT ECONOMICS | RESEARCH ARTICLE

Climate change and inclusive growth in Africa

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Received: 31 July 2023
Accepted: 08 November 2023

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Abstract: Africa's pursuit of inclusive and sustainable economic growth is impeded by many challenges, including climate change, whose effect is most apparent in the continent's tropical regions. To this end, this study investigates the impact of climate change on achieving pro-poor economic growth in Africa. Predicated on poverty-inequality-climate analysis, the Augmented Mean Group (AMG) estimator is used to analyse data from 1996 to 2020 covering 51 African countries. The results reveal that climate change significantly impedes inclusive growth. Furthermore, evidence of a long-lasting negative effect of climate change on inclusive growth, which could be attributed to a lack of coping mechanisms among the poor and vulnerable groups, is found. Finally, the findings show a marginal impact of institutional quality and government spending on inclusive growth in the face of climate change. The study recommends more climate mitigation efforts and enhanced adaptation mechanisms, especially for the poor, as they are most vulnerable to the adverse effects of climate change.

Subjects: Economics and Development; Environment & the Developing World; Sustainable Development; Environmental Economics; Economics

Keywords: climate change; inclusive growth; poverty; income inequality; Africa; sustainability

JEL Classification: I30; O55; Q54

1. Introduction

Climate change remains a crucial impediment in the modern world, as its effects are apparent in almost all spheres of life. It poses a significant threat to the sustainability and inclusivity of societies given its chain impact on macroeconomic factors such as economic growth, inflation, employment, and even migration within and between regions, particularly from rural to urban areas. Nevertheless, there are several efforts to address the causes and ways to mitigate the effects of climate change, including the Paris Agreement's zero-emission pledge to keep global warming below 1.5 degrees Celsius. Climate change has been recognized to be a phenomenal unequalizer; its impact is unevenly felt across countries and regions. Its effects disproportionately affect the world's poorest people and countries, widening existing inequalities and creating new ones across and within countries (Cevik & Jalles, 2023; Tol, 2021). Climate change can also impede a country's drive towards sustainable development and inclusive growth. For instance, through its uneven effect and its demanding coping strategy, it tends to push the poor and vulnerable into extreme poverty while simultaneously widening the income gap. In other words, climate change constituted a severe impediment to pro-poor growth, particularly in developing countries.

Africa is one of the continents enduring a growing impact of climate change in the form of food insecurity, population migration, drought, and stress on water resources, among others. Serdeczny et al. (2017) observes a rising trend in climate change estimates in Africa, particularly in the inland subtropics. This includes the frequent occurrence of extreme heat events, increasing aridity, and changes in rainfall, especially the apparent decrease in Southern Africa and an increase in East Africa. Thus, under a 4°C warming scenario, the region might also witness a one-meter sea-level increase by the end of this century (Serdeczny et al., 2017). More so, Baarsch et al. (2020) noted that climate-induced economic losses are inevitable for the bulk of African economies due to limited response. According to UNCC (2020), 2019 was one of the warmest years on record for the continent and this progressive trajectory is anticipated to continue. Africa's temperatures have risen at a rate equivalent to those of other continents, with mean values that are quicker than the global surface mean value. In addition, it is anticipated that by the latter two decades of this century, many portions of Africa will have warmed up by more than 20°C over pre-industrial levels (UNCC, 2020). Serdeczny et al. (2017) further estimate that historical mean climate-induced losses in Africa was between 10% and 15% of GDP per capita growth, hence, putting most of the economies at a disadvantaged position. Western and Eastern African countries are anticipated to be the most affected on the continent; hence, the increased consequences are projected to impair the income gaps between countries in the higher and lower instances of global warming. This is likely to exacerbate the already immense poverty and high-income gap experienced on the continent.

According to Oxfam (2019), Africa is the second most unequal continent in the world and is home to seven of the most unequal countries. Similarly, Statista[1] estimates that over 460 million people on the continent lived below the extreme poverty line of $1.90 per day in 2022, indicating that approximately one-third of Africa's population was living in extreme poverty in the year. This raises the fundamental question of how inclusive the region's economic growth is. Thus, this study's motivation is premised on the fact that climate change is a growing threat to the sustainability and inclusiveness of societies. As a result, a paradigm shift toward low-carbon and resilient communities and economies is imperative. Given that climate change is a global phenomenon with potential influence on the prevalence of poverty and economic inequality within and between countries, an empirical investigation of the role of climate change in attaining sustainable, inclusive growth is a plausible research objective. This is because, despite being the lowest emitters of greenhouse gases, developing countries are the most affected by climate change (Bhattacharya et al., 2023), particularly in tropical regions, which are naturally hot zones.

To this end, the study contributes to the existing body of literature in several ways. Firstly, it seeks to use a composite measure of inclusive growth. This is premised on the fact that inclusive growth is viewed as a pro-poor growth process. Thus, the two main indicators of pro-poor growth were used: poverty (absolute) and income inequality (relative). The use of a composite index stems from the notion that poverty and income inequality are indicators of inclusive growth from a pro-poor growth perspective; hence, a single index is feasible for comparison. Also, the responses of poverty and income inequality to climate change could be assumed to be identical and interdependent, given the negative feedback. Another contribution of the study is the use of the Palma ratio rather than the Gini coefficient to analyze inequality. The Palma ratio has been suggested as an effective tool for comparing inequality between countries since it considers both top and bottom-income groups. Finally, the study employs a panel model technique to account for cross-sectional dependence due to the interconnectedness of the countries as a result of globalization and economic integration. This study also recommends policy measures aimed at mitigating the effects of climate change on inclusive growth.

2. Literature review

The impact of climate change on poverty is often conditioned by the spillover effect on income equality, which means that as the income gap widens, the incidence of poverty worsens. Hallegatte et al. (2014) identify four channels through which climate change could affect the incidence of poverty. This includes the consumption channel, production channel, asset channel, and productivity channel. These channels are viewed as interrelated. For instance, in the productivity channel, climate change is believed to limit productivity by reducing agricultural output owing to a decrease in rainfall or other natural disasters, such as floods, pest and bug infestations, and droughts. As a result, prices rise, which tends to lower the consumption patterns of consumers, particularly the poor (consumption channel). Thornton et al. (2008) argue that climatic unpredictability is a key element that prevents developing countries, such as those in sub-Saharan Africa, from achieving sustainable development objectives. Most rural residents are poor and vulnerable to climate conditions. In a bottom-up approach, the effects of climate change are more severe on the poor and vulnerable populations since they are more exposed to weather extremism and located in areas prone to environmental disasters (Hallegatte & Rozenberg, 2017). More so, they have a limited potential for adaptation and rehabilitation.

Climate change is not often considered to be the fundamental cause of poverty but could impair its incidence by making the poor more susceptible to instances of poverty (Hallegatte et al., 2018; Hertel & Rosch, 2010; Tol, 2018, 2021). Poorer people are more likely to be impaired by climate change because they have insufficient resources to recover from climate shocks and stress like droughts, hurricanes, and floods. Moreover, the livelihood of the poor is more likely to depend on climate-sensitive sectors (e.g., agriculture, forestry, fishing, pastoralism) or low-income informal or hourly jobs with little protection against climate-related employment disruptions (Brainard et al., 2009; IPCC, 2007; Skoufias et al., 2012).

An extensive literature search reveals a paucity of empirical research on the nexus between inclusive growth and climate change, especially in the context of Africa. The current study do, however, acknowledge existing study on aspects of inclusive growth such as climate change and income inequality (Alam et al., 2017; Cevik & Jalles, 2023; Diffenbaugh & Burke, 2019; Kunawotor et al., 2021; Maurizio et al., 2022; Shayegh & Dasgupta, 2022; Sheng et al., 2023), climate change and poverty (Brainard et al., 2009; Hallegatte et al., 2014, 2018; Hertel & Rosch, 2010; Leichenko & Silva, 2014; Thornton et al., 2008), and climate and economic growth (Alagidede et al., 2015; Batten, 2018; Elshennawy et al., 2016; Iliyasu et al., 2023; Magazzino, 2022; Magazzino & Falcone, 2022; Magazzino et al., 2021; Mele et al., 2021, 2021; Tol, 2021). In addition, Magazzino et al. (2023) also observes a co-movement between economic, energy, and environmental factors over time, implying a relationship between the variables.

The impact of climate change is heterogeneous within and across countries in terms of work and employment. For instance, Hallegatte et al. (2018) argue that because the effects mostly affect low-income persons, the negative welfare implications will be substantially worse than if the burden is shared by those with a higher income. This is because the poor and low-income groups have fewer resources to fall back on and lesser adaptive ability because their resources and income account for a small portion of national income.

Palagi et al. (2022) noted that excessive levels of climatic anomalies not only widen the income gap between countries but also within countries. Through a historical counterfactual study, Diffenbaugh and Burke (2019) find that global warming has hampered the reduction of global economic inequality. Warmer temperatures were also found to enhance economic growth in cold countries while decreasing growth in warm countries. Alam et al. (2017) observe that climate change harms agricultural productivity, profitability, and income inequality since it imposes uneven revenue distribution on farmers. Sheng et al. (2023) find that rising temperatures exacerbate long-term wealth inequality. In addition, it demonstrates a heterogeneous response of wealth inequality to climate risk shocks between regimes with high and low climate risk. Further, Cevik and Jalles (2023) point out that climate change has a positive effect on income inequality. However, in a distributional analysis, the findings reveal that the effect tends to be significant for developing countries but not so for developed countries. An indirect way that climate change can relate to poverty and income inequality is by affecting the labor market and employment opportunities. Climate change can reduce the demand for labor in sectors that are sensitive to climatic conditions, such as agriculture, forestry, fishing, tourism, and construction (Garthwaite, 2019). Climate change can also reduce the supply of labor in these sectors by affecting the health and mobility of workers. These labor impacts can lower the income and welfare of poor people, especially those who rely on informal or seasonal work. Additionally, these labor impacts can increase the inequality between skilled and unskilled workers, as well as between men and women (Garthwaite, 2019).

3. Methodology and data

3.1. Data description and preliminary analysis

The study uses yearly data from 1996 to 2020 covering 51 African countries selected based on data availability. These countries include Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, and Zimbabwe. A composite index for inclusive growth is created using the principal component analysis. The purpose of using an index is premised on two conditions. First, inclusive growth is pro-poor growth which, by definition, is a combination of poverty reduction and income inequality. Secondly, following the survey of the literature, it is observed that the responses of both factors to climate change are interdependent and almost synchronous. Therefore, it is plausible to employ an aggregative measure as an alternative to index decomposition. Palma's coefficient (see equation 1) is adopted as the measure of income inequality. This is defined in Equation 1.

$$PR = {}^{top10\%}/_{bot50\%} \tag{1}$$

Where PR is the Palma ratio, $top10\%$is the income share of the top income group, $bot50\%$ is the income share of the bottom income group. It is important to note that a higher value of the index means a higher concentration of income inequality. In other words, it implies lower inclusive growth.

3.2. Estimation strategy

For model estimations, the Augmented Mean Group (AMG) approach of Eberhardt and Teal (2010, 2011) is utilized. The AMG is an estimated cross-group mean of the evolution of an unobservable element through time, often known as a "common dynamic process". Similar to the Mean group (MG) estimator, the AMG estimator incorporates an intercept that captures time-invariant fixed effects (Eberhardt & Teal, 2010, 2011). This estimator is particularly appropriate for macro panels with moderate T and N. The choice of the method is based on the presumption of cross-sectional dependence and heterogeneity in the model. As noted earlier, climate change is a global phenomenon, there could be potential for a spillover effect between the countries given that they are situated on the same continent, especially in the tropical region. Related studies have used dynamic models such as generalized methods of moments (Khan et al., 2022, 2023) however, while these techniques account for endogeneity in the model, unlike the AMG model, they are weak in accounting for cross-sectional dependence. Other static panel model such as fixed and random effect model also does not account for this issue.

The baseline empirical model is presented as:

$$Incl_{it} = \beta_0 + \beta_2 temp_{it} + \beta_{3i} cont_{it} + \varepsilon_{it} \tag{2}$$

Where $Incl_{it}$ is inclusive growth index, which was derived with the aid of principle component analysis (PCA). PCA is a technique for dimensionality reduction that identifies a set of orthogonal axes, called principal components, that capture the maximum variance in the data (Vyas & Kumaranayake, 2006).

Table 1. Variables description

Variable	Description	Source
Incl.	The composite index of poverty and Palma's ratio using principal component analysis.	Authors' computation
Poverty	Share of population in extreme poverty (in percentage)	World Bank PovcalNet
Palma	The ratio of the top 1% share is the share of income/wealth accruing to the 1% highest incomes/wealth in the country over the bottom 50% share is the share of income/ wealth accruing to the bottom 50% of the population.	Authors' computation using data from the World Inequality Database
Temp.	Temperature anomalies (measured in degrees Celsius)	FAOSTAT
GE	Government final expenditure as a percentage of GDP	World Development Indicators
IQ	Institutional quality: A Principal component of world governance indicators	World Governance Indicators
Fossil	Fossil fuel energy consumption (% of total)	World Development Indicators
**Pop.	Total population	World Development Indicators
**GDP	GDP (constant 2015 US$)	World Development Indicators

**** Data was transformed to log form.

The principal components are linear combinations of the original variables in the dataset and are ordered in decreasing order of importance (Vyas & Kumaranayake, 2006). In the current study, we applied it to the two variables of inclusive growth i.e. poverty and inequality. Here, it is important to note that the first principal component will explain most of the variance in the data, while the second one will explain the remaining variance. Thus, we relied on the first component since the technique was used to create an index. The creation of the index was implemented with the aid of STATA software. More so, studies such as Nchake and Shuaibu (2022) applies similar techniques in deriving an inclusive growth index. $temp_{it}$ is temperature anomalies, a proxy for climate change. $cont_{it}$ are the control variables such as government expenditure, institutional quality, economic growth, population, and fossil fuel consumption. It is anticipated that a substantial portion of government expenditures would go toward providing social security and safety nets for the poor and vulnerable. Through redistribution or spending, government spending should always be the primary tool for fostering pro-poor economic growth. In this context, institution quality is crucial since weak institutions impair the performance and effectiveness of governance. Furthermore, they might impose economic and structural restrictions in order to reduce poverty and income inequality. Acemoglu et al. (2006) argued that weak institutions make economic activity inefficient, which can impede long-term economic progress and exacerbate the incidence of poverty. Positive economic growth, on the other hand, means additional resources for redistribution as well as the provision of social security and protection for the poor and vulnerable. However, there are some criticisms in this regard. For instance, Ravallion et al. (2007) emphasize that economic progress might deepen income inequality, which could hinder poverty reduction efforts. Population increase overextends available resources and causes strong competition for them. In addition, resource demand pressure may lead to deforestation, which hurts the anthropological climatic influence on the environment. Fossil fuels continue to be the cheapest source of energy for the poor and vulnerable. However, this harms the environment because it is ecologically unfriendly.

Table 1 provides the variable description and Table 2 provides an overview of the descriptive statistics of the variables. As seen by the minimum and maximum values of −1.7 and 8, respectively, the pro-poor growth in Africa remains noticeably weak, with disparities between countries. This is further confirmed by the fact that the standard deviation value is larger than the mean value, indicating considerable dispersion. The maximum values for the Palma coefficient (overall, between, and within) indicate significant income inequality on the continent. The overall sample demonstrates, for instance, that the top 10 percent of income group shares are 12 times more than the lowest 50 percent. In a similar view, the maximum percentage of individuals living in severe poverty is around 95% (in the case of the overall sample). This high number demonstrates the compelling need to address the issue.

4. Results and discussion

The pre-estimation tests of cross-sectional dependence (CSD) of Pesaran (2004) and the slope homogeneity test of Pesaran and Yamagata (2008) were conducted. The CSD test result presented in Table 3 reveals interdependence across countries. This implies the existence of impact spillover between countries in terms of climate change vulnerability. This finding also bolsters the use of estimating techniques that account for cross-sectional dependence. The slope homogeneity test was conducted to assess whether the slope parameter, such as climate change anomalies, is homogeneous or heterogeneous across countries (see Table 4). The outcome demonstrates the absence of a homogeneous impact. This supports the argument that the impact of climate change varies between regions and countries. Figure 1 also depicts a diagrammatic mean average of

Table 2. Descriptive statistics

Variable	sample	Mean	Std. Dev.	Min	Max
Incl	overall	2.67E−10	1.076	−1.716	8.062
	between		0.952	−1.613	2.259
	within		0.518	−1.405	5.803
Palma	overall	1.575	1.034	0.511	12.325
	between		0.858	0.523	4.541
	within		0.588	−0.609	10.269
Poverty	overall	0.358	0.267	0.000	0.953
	between		0.236	0.000	0.822
	within		0.131	−0.465	0.800
Temp	overall	0.878	0.469	−0.663	2.595
	between		0.241	0.321	1.550
	within		0.404	−0.652	2.487
IQ	overall	−2.59E−09	2.194	−6.262	5.517
	between		2.118	−5.181	5.012
	within		0.645	−2.872	2.662
GDP	overall	22.966	1.594	18.867	26.974
	between		1.556	19.362	26.351
	within		0.441	19.858	24.331
GE	overall	15.343	7.309	0.911	62.133
	between		6.834	4.454	38.688
	within		3.838	−0.770	46.018
Pop	overall	15.808	1.596	11.244	19.144
	between		1.171	13.038	17.498
	within		1.100	11.812	19.623
Fossil	overall	39.104	32.388	0.000	99.978
	between		32.930	0.000	99.794
	within		4.786	19.740	54.586

Table 3. Cross-sectional dependence test

Variable	CD-test	P. value	corr	abs(corr)
Incl	29.25	0.00	0.172	0.582
Temp	91.02	0.00	0.525	0.529

Source: Author's computation

Table 4. Slope homogeneity test

	Delta	p-value
	5.664	0
adj.	9.281	0

H0: slope coefficients are homogenous.

Source: Authors' computation.

temperature anomalies and inclusive growth. We observed an uneven distribution of countries, with most of them clustered near the middle.

The panel unit root test of Pesaran (2007) was carried out which revealed that the key variables inclusive growth and temperature anomalies were stationary at levels. This further lends support to the use of the AMG technique (see Table 5).

Following the battery of preliminary tests, equation 2 was estimated using the AMG model and the results are presented in Tables 6–8. The diagnostic test reveals the robustness of the estimated models following the probability values of the Wald Chi statistics and the relatively low value of the root mean squared error (RMSE). For the results presented in Tables 6–8, the robust standard errors are reported. However, the results with the conventional standard errors are presented in Tables A1–A3 in the appendix. From Table 6, the coefficient of the temperature anomaly indicates that climate change has a positive and significant impact on the composite inclusive growth variable. Considering the construction of the variable, this implies that a rise in temperature anomaly (a warmer climate) increases the incidence or concentration of poverty and income inequality thereby impeding inclusive growth. This finding aligns with the assertion of (Alam et al., 2017; Cevik & Jalles, 2023; Hallegatte & Rozenberg, 2017; Tol, 2021) on climate change's effect on poverty and income inequality. As previously stated, climate change anomalies impact poverty and income inequality through several mechanisms that are specific to Africa. These include consumption, production, and opportunity channels, which are, incidentally, intertwined. We may contend that a large chunk of the African population resides in non-urban areas and subsists in agriculture. These regions are the most susceptible to the effects of climate change due to the aforementioned channels.

Institutional quality is found to be negative but not statistically significant. This finding reveals Africa's weak institutional quality, hence the failure of institutions to facilitate a reduction of both inequality and poverty. GDP growth is found to significantly reduce the combined effects of inequality and poverty. This implies that as the economy expands, more resources are available for distribution in the form of income and social capital to the poor and vulnerable sections of the population. Besides, economic growth might be accompanied by a reduction in unemployment, thereby improving the income of those at the bottom of the economic ladder. Government spending is found to have an insignificant effect. This is not surprising considering that a large chunk of government spending in the region is on recurrent outlays with capital and social expenditure receiving relatively less attention.[2] This could increase the vulnerability of the poor to climatic factors.

The positive effect of population growth indicates that population expansion exerts more strain on the available resources of countries, thereby aggravating poverty and inequality. It could also reduce the

Figure 1. Relationship between climate change and inclusive growth.

Source: Authors' computation.

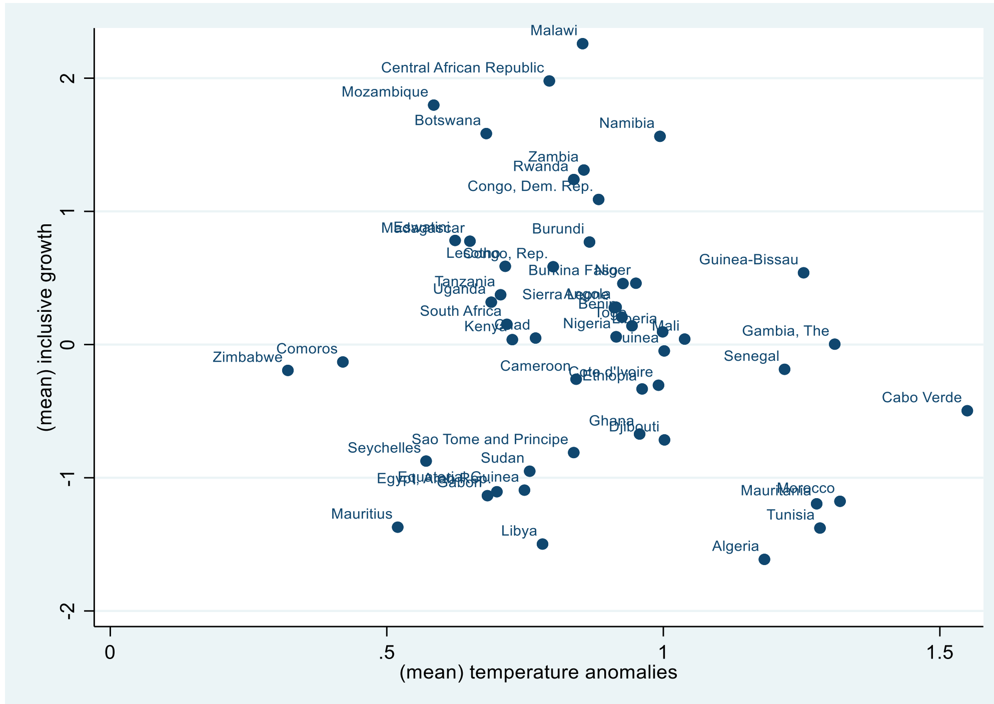

Table 5. Cross-sectional panel unit-root test		
Variable	**Z-Bar**	**P. value**
Incl	−3.828	0.000
Temp	−13.315	0.000

Source: Authors' computation.

Table 6. Inclusive growth and climate change		
Dep. Var.: Inclusive growth measure	**Coef.**	**Std. Err.**
Temp	0.052***	0.020
IQ	−0.007	0.022
GDP	−0.491**	0.234
GE	−0.001	0.002
Pop.	0.272**	0.121
fossil	0.001	0.005
cdp#	0.632	0.551
_cons	1.188	5.618
Wald Chi (P.value)	16.46 (0.0115)	
RMSE	0.0487	

*Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, #cdp is common dynamic process.*

Source: Authors' computation.

Table 7. Inclusive growth and climate change (with lag)

Dep. Var.: Inclusive growth measure	Coef.	Std. Err.
lag(temp)	0.042***	0.014
IQ	−0.002	0.023
GDP	−0.486**	0.229
GE	0.000	0.002
Pop.	0.269**	0.133
fossil	0.003	0.005
cdp#	0.688	0.646
Constant	−0.461	5.471
Wald Chi (P.value)	17.43 (0.008)	
RMSE	0.0495	

*Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, #cdp is common dynamic process.*
Source: Authors' computation.

Table 8. Inclusive growth with temperature and lag

Dep. Var.: Inclusive growth measure	Coef.	Std. Err.
temp	−0.093	0.058
lag(temp)	0.086*	0.051
IQ	−0.015	0.027
GDP	−0.516***	0.192
GE	0.000	0.002
Pop.	0.144*	0.080
fossil	−0.001	0.004
cdp#	0.735	0.672
Constant	3.361	4.242
Wald Chi (P.value)	16.39 (0.022)	
RMSE	0.047	

*Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, #cdp is common dynamic process.*
Source: Authors' computation.

per-capita resources directed toward mitigating climate-related effects. Although the affluent may be able to maintain their standard of living and resources with a larger population, this is not the case for the poor, who are compelled to reduce their consumption to accommodate population growth. Fossil fuel usage has a negative but insignificant impact. Despite its negative environmental impact, conventional fossil fuel remains a cheaper and more accessible source of energy in developing economies, thereby making its use commonplace.

Given the assumption that the impact of climate change may be long-lasting, we performed a historical dependence analysis using the lagged value of the temperature in Table 7. The addition of the lag variable is intended to indicate if the effect of climate change is sustained through time. For example, if the prior climatic condition persists until the current period. Given extreme climatic conditions in the preceding year, there may be a low yield or shortfall of output in the current year, as the response may not be quick in some instances. The estimate in Table 7 reveals that the effect is positive and statistically significant at 1%. This suggests that climatic conditions have a lasting impact on the concentration of poverty and income inequality. Given the limited resources and high susceptibility of the poor who reside in regions most impacted by climate change, this demonstrates a lack of or inadequate coping strategies. The effects of climate change might become cumulative and cyclical.

For robustness checks, the study included both the temperature variable and its lagged value in the model (see Table 8). The magnitude of the estimates of the variables is identical, but it can be seen that the lagged variable is statistically significant (i.e., at 10 percent) against the absolute variable, suggesting that the lagged temperature effect is more apparent. In other words, inclusive growth generates a historical dependence on climate change.

5. Conclusion

This study investigates the impact of climate change on Africa's quest to achieve inclusive and sustainable growth. To achieve this, the study conceived inclusive growth in terms of absolute pro-poor growth (poverty) and relative pro-poor growth (income inequality). This study is predicated on the transmission channels of consumption, production, and opportunity. The study contributes to the existing literature by examining how anthropogenic climate change may inhibit the attainment of sustainable inclusive growth, particularly in tropical developing countries that have experienced the most climate change impacts. The study finds a negative effect of climate change on inclusive growth via the worsening of inequality and poverty. Further, the negative effect of climate change on inclusive growth is long-lasting.

The study recommends concerted efforts to mitigate the adverse effects of climate change on the poor and vulnerable. One way to achieve this is to institutionalize climate response programs and schemes, particularly in rural regions where climate change impacts are severe. In addition, as climatic shocks cannot be averted in most situations, the government should pay more attention towards augmenting the coping mechanisms of the poor and vulnerable. A complete transition to cleaner energy may be a long-term objective, especially in the case of Africa, however, measures could be put in place to begin a gradual transition from the use of fossil fuel. This is because cleaner energy could be cost-intensive in the short term as fossil energy is pro-poor (despite being a driver of climate change). Hence, it will be crucial for coping strategies such as the provision of social protection and safety nets for the poor and vulnerable to be in place during the transition. One limitation of the study centres around the unavailability of data on other climatic-related factors such as drought and flooding which are peculiar anthropogenic factors in Africa. This limits the scope of the study to temperature anomalies as the main indicator for climate change. For future studies, the study recommends the use of Artificial Intelligence experiments to carry out a simulated analysis of the impact of climate change on inclusive growth.

Acknowledgement
The APC payment by the University of the West of Scotland is greatly appreciated.

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Citation information
Cite this article as: Climate change and inclusive growth in Africa, Suleiman O. Mamman, Kazi Sohag & Attahir B. Abubakar, *Cogent Economics & Finance* (2023), 11: 2282869.

Notes

1. https://www.statista.com/statistics/1228533/number-of-people-living-below-the-extreme-poverty-line-in-africa/
2. See Ortiz-Ospina and Roser (2016)

Data availability statement
The data used for this study is available upon request.

Declaration
The authors have no competing interests to declare.

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Appendices

Table A1.

Dep. Var.: Inclusive growth measure	Coef.	Std. Err.
Temp	0.0515***	0.017
IQ	−0.048	0.046
GDP	−0.48147*	0.269
GE	0.006	0.005
Pop.	1.092*	0.582
fossil	−0.002	0.008
cdp	1.415*	0.742
_cons	−7.064	7.335
Wald Chi (P.value)	19.73 (0.003)	
RMSE	0.0487	

*Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$*

Table A2.

Dep. Var.: Inclusive growth measure	Coef.	Std. Err.
lag(temp)*	0.024*	0.014096
IQ	−0.06*	0.033276
GDP	−0.3691	0.282272
GE	0.009**	0.004287
Pop.	1.093	0.701119
fossil	0.0021	0.010701
cdp	1.797**	0.839628
Constant	−10.507	8.960932
Wald Chi (P.value)	28.45 (0.000)	
RMSE	0.0495	

*Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$*

Table A3.

Dep. Var.: Inclusive growth measure	Coef.	Std. Err.
temp	0.037*	0.019476
lag(temp)	0.035**	0.016153
IQ	−0.073*	0.04255
GDP	−0.423	0.293086
GE	0.008**	0.004082
Pop.	1.099*	0.661343
fossil	0.004	0.009308
cdp	1.691**	0.81465
Constant	−9.09	8.157253
Wald Chi (P.value)	15.29 (0.032)	
RMSE	0.047	

*Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$*