International Journal of Humanities Social Science and Management (IJHSSM)
Volume 3, Issue 1, Jan.-Feb. 2023, pp: 610-622 www.ijhssm.org

Impact of Climate Change on the Economic Growth and Employment in Selected African Countries

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Date of Submission: 14-02-2023 Date of Acceptance: 28-02-2023

Abstract
The exposure of most African countries to the elements of climate change has grossly impacted the output of the economies, especially the agricultural sector. This work examined the impact of climate change on economic growth and employment in ten African countries between 1997 and 2021. The study employed Panel Autoregressive Distributed Lag Model with the Pooled Mean Group estimator. The findings showed that all the climate change variables, such as precipitation, carbon emissions, temperature, labour employed and physical capital are statistically significant in affecting GDP growth in all the countries in the long run. It was also revealed that all the variables of climate change are significant in affecting labour employed in the countries. Further inquiries into the effect of climate change on agriculture and the energy sector showed that precipitation affects agriculture more than the other factors, while carbon emissions and temperature are statistically significant in affecting energy demand. It was therefore recommended that one strategy to combat climate change on GDP growth and the sectors is through adaptation of modern technologies in the farming process to preserve the soil and make the crops more resilient.
Key Words: Climate, Gross Domestic Product, Carbon emission, Energy demand, Temperature

I. Introduction

Every attempt to boost the growth of any economy through industrialization has bred some negative consequences in terms of the generation of Greenhouse gas which has exacerbated the breakdown of the ozone layers through global warming. Pachauri, et al (2014) have the record that more than ninety-seven per cent of authors on global warming have agreed that global warming has been described as the rise in the earth's temperature essentially due to human activities through the burning of fossil fuels, bush burning (IPCC, 2013). A strong area of interest in the environmental economics literature is the link between climate change and the productivity of an economy. The elements of climate change that are usually considered and will be adapted in this work are rainfall, carbon emission and temperature because these are the three elements that are most relevant to the African sub-region under consideration.

While attempting to foster growth and maintain a healthy environment, there are two schools of thought on the nexus between the environment (climate) and economic growth or development. The prominent and negative view opined that to maintain a healthy environment or sustain climatic conditions, economic growth should be sacrificed because it is almost impossible from the traditional view to get industrialized and develop in terms of automobile and mechanical developments that depend on the use of hydrocarbon commodities without negatively affecting productivity. On the other hand, the second school of thought leans more towards green technologies that advance productivity, consumption and development and consequently productivity(Alagidede, et al, 2015). In other words, high-level technology needs not to be at the expense of high-level productivity. What this implies is that if there can be the development of cost-effective equipment and instruments in tackling the global rise in temperature, that technology would not impede growth in the long run.

Climate change indeed takes its toll in virtually all countries of the world, but its effect will be more significantly felt in low-income countries like the Sub-Sahara Africa (SSA) countries. This is because most of these low-income countries rely heavily on agriculture and other sectors, such as fishing that are sensitive to climate change for both employment and production. In addition to this exposure, most of these countries have little capacity to respond to the shocks from these climate

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change (Lanzafame 2012, Stern 2006).In a report by UNEP, AfDB and ECA (2019), some countries in Africa will suffer hugely in terms of percentage change in GDP as a result of global warming. For instance, Sudan (-18.6), Tanzania (-18.6), Liberia (-16.9), and Guinea-Bissau (-16.7). A major factor that would account for this great change is the lack of capability for adaptation.

The direction of the impact of climate change on the gross domestic product is likely going to be the same as climate change and employment. A negative relationship between climate change will generate a negative effect on employment. A climate change that results in flooding, for instance, will destroy a lot of the farmlands, livestock and ponds, and therefore render the majority of the farmers, herders and fishers jobless. This trend will most probably discourage farming in the coming seasons and that will generate medium-term unemployment. On the flip side, a lack of enough rainfall will affect crop yields and low harvests per season (OECD, 2010).The study report of ADB (2009) showed that by 2050, if the trend of climate change continues, production of some agricultural outputs will decline, such as, rice will fall by between 4-20 per cent, wheat will decline by 32–44 per cent, maize will fall by 2-5 per cent and soya beans will decline by between 9-18 per cent. Similarly, high temperatures beyond the expected could cause heat stress and lead to a reduction in the number of work hours. In a developed economy where climate change adaptation is being achieved, it will however yield a positive result on employment and boost productivity. ILO (2019) reported that global warming has been found to increase work-related stress predominantly in tropical and subtropical regions, causing job and productivity losses to the tune of 80 million jobs. It was further confirmed by the author, that an increase in temperature of about 1.5ºC will result in about a 2.2 per cent loss in work hours and about $3.2 trillion loss in productivity by 2030.

Changes in the climatic elements such as increased rainfall, and increased temperature have had untold effects in some of the SSA countries, especially, Nigeria in the last decade. This increase in rainfall had led to unusual flooding that has washed off many farmlands, destroyed huge livestock, destroy homes and farm settlements, and rendered millions homeless and jobless. In 2020, Agriculture contributed about 18.9% to Ghana's GDP, 21% to Nigeria's GDP and 2.5% to South Africa's GDP.

Table 1.1: Extract of Effect of flooding in selected countries in SSA

Country	Area Covered	No of Death	No affected	No injured
Nigeria	33 states	612	7,000,000	5,000
Rwanda	Across the Country	15	-	37
Central African Republic	176 towns	11	85,300	2,600 houses
Cameroon	Northern Cameroon	2	37,430	95
Chad	-	22	17,000	229
Niger	-	168	227,000	-

Source: Author generated from different sources

Table 1 presents a glimpse of the effects of flooding associated with climate change on different countries in the SSA. These dimensions of effects are only approximated because of the data collection problem. Several deaths, injuries, displacement, loss of jobs, loss of residential buildings, businesses, and eventual loss of productivity occurred. Without the effect of mitigation and control, the negative effect of climate change on global GDP will likely rise over time between 1.0 to 3.3 per cent by 2060. Similarly, as temperature increases to a projected level of 4ºC by 2100, this may slow down GDP by between 2 to 10 per cent by 2100 (OECD, 2015). The sector that is more vulnerable to these rises in temperature and rainfall changes is the agricultural sector and more precisely, the crop production sub-sector and labour productivity (OECD, 2015).

An interesting debate in environmental studies is to find out if reducing carbon emission that is generated from the most industrial production process and mobility can affect production positively. Traditionally, growth in industrialization leads to growth in greenhouse gas emissions and greenhouse gas emissions lead to global warming. If the trend is allowed to continue, it implies that global warming will not be reduced and that could bring about a negative effect on the economies. The argument therefore is, can we have a de-link between carbon emission and economic growth? In other words, can we actualize the Paris climate agreement that is aimed at reducing climate change

disasters? Aden (2016) was very emphatic about the fact that it is possible in this 21st century to increase economic growth and reduce carbon emissions. For most African countries, this assertion is not yet a reality in their growth process. The reason is that most African countries are still operating with the mentality of the Industrial age, where they need to make use of fossil fuel energy resources and are not prone to energy efficiency and conservation technologies that will help to reduce the amount of greenhouse gasemissions and at the same time increase output. The relationship between greenhouse gas emissions and GDP is connected toa reduction in labour productivity, diseases contracted through inhaling polluted air and shortening of life expectancy, absence from work and at the same time lowering crop yields.Preventing carbon emissions and cleaningthe air can reduce deaths by about 17,000 and increase national income by £1.6 billion (Confederation of British Industry, 2020) and it was also found that air pollution cost India about $95 billion in 2019 (Newton-Smith, 2020). The essence of this narrative is to show that carbon emissions exerts a negative impact on productivity of an economy.

This study is focused on examining the impact of climate change on the gross domestic product and employment in some African countries using panel vector Auto regression. This is what Auffhammer (2019) referred to as damage function. It will also examine the impact of climate change on some sectors like agriculture and energy. The rationale for this is to find out which of these sectors of the economy is most affected by climate change. The countries to be used will be informed by the availability of data on the climate change variables, such as rainfall, temperature, unemployment, agricultural output, fishery output and overall GDP of the countries. The value addition of this work is the examination of climate change's impact on employment and some sectors. Most studies in the past have only been able to consider either climate change's impact on GDP or on one or two of the sectors of an economy.

The remaining sections of this study are divided into six. Section two will present the available recent literature, section three will show the theoretical framework underlying this study, section four will indicate the methodology, model specification and data sources for the estimation, section five will present the discussion of results and section six will give the conclusion and policy recommendations.

II. Empirical Review

In the work of Khurshid, Fiaz, Khurshid and Ali (2022), it was shown that Pakistan has one of the lowest contributions to the emission of greenhouse gas, and yet, it is one of the hardest hit nations by climate change and this prompted their search on the effect of climate change on the economic growth of Pakistan between 1980 and 2021. They employed the nonlinear ARDL for the estimation of the impact of rainfall and temperature on the growth of GDP in the country. It was discovered from the estimated results that temperature had a nonlinear relationship with economic growth while precipitation has a positive and statistically significant effect in the long run with economic growth. The work recommended high-level mitigation both at the national and global levels to offset the negative effect on the economy of Pakistan. Bodjongo (2022) on the other hand examined the impact of climate change on cotton prices and production between 1985 and 2015 in Cameroon and using a Vector Autoregressive methodology, the result indicated that warmer temperature was good for cotton production in the country. It should be noted that the warm temperature may become hazardous to labour productivity after a while and lead to unemployment.

The work of Tetteh, Baidoo and Takyi (2022), examination of the effect of climate change on food production in Ghana between 1970 and 2019 using temperature, rainfall and CO_2 as climate change variables, with cointegration methodology. The findings showed that temperature had a negative effect on all the crops but moderate rainfall exhibited positive results on the crops, however, carbon emission was detrimental to the crops. The recommendation was to develop temperature-resilient crops to improve food production.

In another study, Kadanali and Yalcinkaya (2020) carried out a study on the effect of climate change on economic growth in 20 top economies of the world to establish the asymmetric or symmetry relationship between climate change and economic growth between 1990 and 2016 while using panel regression analysis. The finding showed that climate change had a negative and statistically significant effect on the economic growth of the nations. It was therefore recommended that efforts for adaptation should be improved and efforts to reduce greenhouse gas emissions should be encouraged. Gupta, et al, (2020), on the other hand, studied the effect of climate change in India, using a descriptive methodology and they found that a decline in rainfall, an increase in temperature, and CO2

emission have negative effects on agricultural productivity in the country. Beyond that, it was found that high temperature reduces the underground water and creates an environment where pests and diseases can thrive.

Kahn, Mohaddes, Ryan, Pesaran, Raissi and Yang (2019) carried out a study on the impact of climate change in the long run on 174 countries over the period between 1960 and 2014 and using a stochastic growth model with panel regression, where they allow the country-specific climate to affect labour productivity, using temperature and precipitation as climate change elements. The finding showed that persistent temperature changes affect the per capita output negatively and there was no significant effect of precipitation on growth. Numerically, it was found that a change in temperature of up to 0.04ºC per annum, will have a negative effect on world GDP by up to 7 per cent by the year 2100 if there is no significant mitigation. The study went ahead to experiment with the effect of climate change on some 48 United States of America states between 1963 and 2016 and it was revealed that climate change has a long run effect on the output of these states in real terms in virtually all the sectors as well as on labour productivity and employment in those states.

Ogbuabor and Egwuchukwu (2017) carried out an investigation on the effect of climate change on the Nigerian economy between 1981 and 2014 and using the methodology of Ordinary Least Squares (OLS) and using rainfall, CO_2 and forest depletion as measures of climate change, the findings revealed that CO_2 affects economic growth both in the short and long run, while forest depletion has a short run negative effect.

Agbola and Fayiga (2016) contributed to the debate on the effect of climate change on agricultural output by investigating this effect on Nigeria's agricultural output and their findings showed that extreme climatic situations such as flooding, high temperature and drought have severe consequences on soil degradation and consequently agricultural output.

Alagidede, George, and Prince (2015) made their contribution to the ongoing research on climate change by looking at the effect of climate change on the sustainability of economic growth in 18 Sub-Saharan African countries between 1970 to 2009. Their work employed panel cointegration methodology and it was discovered from their findings that a temperature above 24.9ºC will negatively affect economic performance it also revealed that the relationship between temperature and Gross Domestic Product per capita is nonlinear over time.

The study conducted by Cian and Wing (2014) on climate change's impact on energy demand using a panel analysis of 29-48 countries between 1978 and 2010, with some meteorological elements data to represent climate change and some variables of energy demand such as electricity, gas, heating oil, etc. The findings of the study revealed that the response to energy demand varies from sector to sector. It was shown that electricity demand for cooling was larger in temperate regions especially for residential and commercial buildings, while heating oil demand was higher in tropical regions. It was also found that the demand for electricity for cooling the in theindustrial sector was higher in the tropical regions the and demand for oil for heating was also higher in temperate regions.

Lanzafame(2012) in his research on investigating the effect of rainfall and temperature on the economic growth of Africa using the Autoregressive Distributed Lag Model and panel estimator, the findings showed that temperature had both short and long-run effects on per capita growth of African countries, however, the effect of rainfall did not show any significant effect on it. The data was also used to test the effect on the Sub-Saharan African countries, and the outcome supports the earlier results. The work of Akram (2012) examined in some Asian countries, the impact of climate change on the growth of the economies of these countries from 1979 to 2009. The work employed a panel regression with seemingly unrelated regression models founded on the growth model that utilized rainfall and temperature as determinant variables. The results of the estimation showed that rainfall and temperature exerted a negative influence on the economic growth of the countries under study, in the same vein, it was revealed that the most vulnerable sector is the agricultural sector while the manufacturing sector is the least affected. Nastis, et al. (2012) investigated the effect of climate change on Greece's agricultural output between 1980 and 2007. The authors employed Ordinary Least Squares regression and it was found that climate change has already begun to affect agricultural output and there is s need to embark on climate change adaptation to reduce the impact dramatically.

III. Theoretical Framework

This work tried to examine the impact of climate change on economic growth and unemployment in selected African countries. On this basis, two approaches will be adopted. The first is to consider the effect of climate change on economic

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 3, Issue 1, Jan.-Feb. 2023, pp: 610-622 www.ijhssm.org

growth and then on unemployment. We, therefore, present a theoretical framework for the two approaches separately.

The first leg examines the effect of climate change on economic growth and this will be hinged on the two approaches developed by Nordhaus (1991), Cline (1994) and Tol (1995) in analyzing the effect of climate change which emerged from the change in social welfare arising from climate change. They are enumerative and dynamic approaches. The first one attempts to examine the impact of climate change as it affects sector by sector of the economy, such as the impact of climate change on agriculture, manufacturing, energy, etc. This method is limited because it only considers one period and fails to examine the intertemporal relationships among the variables.

The second approach: the dynamic approach tends to employ different models of economic growth by integrating damage function. To estimate this model, the Solow-Swan and Ramsey-Cass-Koopmans are usually employed. When we bring to the fore, the assumption of a constant saving rate, any time climate change affects output negatively, this will lead to a fall in investment and this will lead to a decline in the consumption per capita and capital stock in the economy, which spills over to negatively affect aggregate demand and consequently affects GDP negatively. Lecocq and Shalizi (2007) further opined that the effect on output will be further declined under the endogenous growth model because the lower investment will slow down technical progress and further weakens productivity and human capital development.

The second leg of the work looked at the impact of climate change on employment in African countries. Considering the original work of Okun on the unemployment and economic growth relationship, it was asserted that an increase in unemployment translates to a fall in economic growth by about 3-4 per cent (Okun, 1962). The author did not find any direct empirical literature that addresses climate change and unemployment, but rather climate change adaptation. However, from the empirical facts confronting African countries, especially the flooding saga, where several have been rendered homeless in IDP camps and rendered jobless, it would be appropriate to look at the effects of flooding arising from climate change on employment in these countries.

3.1 Theoretical Model

The first theoretical model addresses the impact of climate change on economic growth and this work is adapting the works of Dell, Jones and Olken (2008) and Akram (2012) where climate variables were introduced into the production function as input to the production process. The two works introduced a production function of this type:

$$Q_{it} = e^{\rho T_{it}} P_{it} L_{it} C_{it} \quad (3.1)$$

$$\frac{\Delta P_{it}}{P_{it}} = h_i + \omega T_{it} \quad (3.2)$$

Where Q is aggregate output, L is labour force, C is human capital, P is labour productivity, T is the impacts of climate change, h is the growth rate of GDP.

Equation (3.1) shows the direct or level effects of climate change on economic growth, for example, the effect of rainfall or temperature on crop yield or livestock and equation (3.2) expresses the dynamic effect of climate change on growth and this shows the growth effect of climate change. For example, climate change could affect labour productivity, or energy, which in turn affects productivity. To transform equation (3.1), we then log and difference it with respect to time and that gives:

$$q_{it} = h_i + (\rho + \omega)T_{it} - \rho T_{it-1} \quad (3.3)$$

Where q_{it} is the growth rate of output, ρ and ω are the direct and indirect effects of climate change on economic growth respectively, while h_i shows the fixed effects.

Both the direct and indirect effects have an influence on economic growth initially, but when the climate returns to normal, the direct effect cancels out and reverses. On the other hand, the indirect effect remains even when the normal climate is maintained. This effect shows up mostly during climate shocks and their effects are not quickly cancelled out. An example could be the lack of proper development in human capital which indirectly influences growth even when climate change is normalized.

The second leg of this work presents the impact of climate change on unemployment in African countries. The work of Carruth, Hooker and Oswald (1998) modified the work of Shapiro and Stiglitz (1984) where equilibrium unemployment was modelled to depend on some inputs prices and it was expressed functionally as:

$$U = f(i, O_p \text{Ub}, \text{ef}, \text{sh}) \quad (3.4)$$

Where U is the unemployment rate, i is the rate of interest, O_p is the price of oil, u_b is unemployment benefits, ef is on-the-job effort and sh is the probability of shirking at work.

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 3, Issue 1, Jan.-Feb. 2023, pp: 610-622 www.ijhssm.org

Adapting model (3.4) to the climate change environment, we know that too much rainfall, affects farmers and render many of them jobless for several months, similarly when the temperature is too high, it affects work incentive, especially those doing manual work like farmers, people on construction, factory workers, etc. In addition, when there is excessive greenhouse gas emission, that affects the ozone layers, the consequence comes in terms of heavy rainfall and high temperature and these tend to have a negative effect on employment. On the other hand, when there is enough adaptation, where farmers can adapt like using high-level equipment to farm, then the temperature will not influence their job. But it will take a lot of financial investment to mitigate the effect of rainfall deluge on the farmers. The only adaptation is to migrate to areas that cannot be affected by flooding and it is not in the short run.

The theoretical model for unemployment, using employment as a dependent variable will be:

$$Lemp_{it} = \pi_0 + \pi_1 RF_{it} + \pi_2 TM_{it} + \pi_3 CO2_{it} + \pi_4 C_{it} + \varepsilon_{it} \quad (3.5)$$

IV. Methodology and Empirical Model Specification

Following the theoretical model, an econometric model, which represents a reduced form of growth equation is expressed as:

$$q_{it} = \beta_0 + \beta_1 RF_{it} + \beta_2 TM_{it} + \beta_3 CO2_{it} + \beta_4 Lemp_{it} + \beta_5 C_{it} + \mu_{it} \quad (4.1)$$

Where q_{it} is the growth rate of GDP, RF is the rainfall, TM is temperature, CO_2 is the greenhouse gas emission, Lemp is labour employedand C is physical capital and μ is the error term. In this study, we will attempt to check on which sector climate change has the strongest effect, and that brings us to the estimation of the following models on Agriculture (Ag), Energy Demand (ED) and labour employed.

Equations (4.1) to (4.5) will be estimated.

$$Ag_{it} = \beta_0 + \beta_1 RF_{it} + \beta_2 TM_{it} + \beta_3 CO_{2it} + \beta_4 Lemp_{it} + \beta_5 C_{it} + \mu_{it} \quad (4.2)$$

$$ED_{it} = \beta_0 + \beta_1 RF_{it} + \beta_2 TM_{it} + \beta_3 CO_{2it} + \beta_4 Lemp_{it} + \beta_5 C_{it} + \mu_{it} \quad (4.3)$$

$$Emp_{it} = \beta_0 + \beta_1 RF_{it} + \beta_2 TM_{it} + \beta_3 CO_{2it} + \beta_4 C_{it} + \mu_{it} \quad (4.4)$$

4.1 Panel ARDL model specification

Based on the cross-sectional and time series data involved in this study, a panel analysis will be best suitable having tested for unit root in all the variables and found that they are all a mixture of I(0) and I(1), we can then employ the Panel ARDL for the estimation of the parameters.

A generalized Auto regressive distributed lag model of (p, q, …q) model is modelled as:

$$y_{it} = \sum_{j=1}^{p} \delta_i y_{i,t-j} + \sum_{j=0}^{q} \boldsymbol{\beta}_{ij}' \boldsymbol{X}_{i,t-j} + \theta_i + e_{it} \quad (4.6)$$

Where y_{it} is the dependent variable, $(\boldsymbol{X}_{i,t})'$ is a kx1 vector that is allowed to be purely I(0) or I(1) or cointegrated, δ_i is the coefficient of a lagged dependent variable, called scalars, β_{ij}' are kx1 coefficient vector, θ_i is the unit-specific fixed effect, I =1……N, t = 1. ….T, p, q are optimal lag orders and e_{it} is the error term.

The error correction model can be specified when the ARDL model (4.6) is re-parameterisedand that gives us equation (4.7), which is the error correction model.

$$\Delta y_{it} = \omega_i [y_{i,t-j} - \boldsymbol{\rho}_i' \boldsymbol{X}_{i,t-j}] + \sum_{j=1}^{p-1} \emptyset_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \boldsymbol{\beta}_{\boldsymbol{ij}}' \Delta \boldsymbol{X}_{i,t-j} + \theta_i + e_{it} \quad (4.7)$$

Where:

$\omega_i = -(1-\delta_i)$ group-specific speed of adjustment and it is expected to be < 0

$\boldsymbol{\rho}_i'$ = vector of the long-run relationship

ECT = $[y_{i,t-j} - \boldsymbol{\rho}_i' \boldsymbol{X}_{i,t-j}]$ = Error Correction Term

$\emptyset_{ij}$ and $\boldsymbol{\beta}_{\boldsymbol{ij}}'$ are the short-run dynamic coefficients

Equation (4.7) will be estimated with Pooled Mean Group (PMG) estimator introduced by Pesaran and Shin (1999). This estimator assumes that the long-run coefficients are homogenous across groups and the short-run coefficients vary across groups. This estimator is an intermediate approach between the Dynamic Fixed Effect (DFE) and Mean Group (MG) estimators. PMG estimator is therefore based on a lower degree of heterogeneity in the long run and short run heterogeneity. This means that the estimator does not impose equality of slope coefficients in the short run and thereby allows dynamic specification, that is, the number of lags included to differ across groups. As a result of the long-run slope homogeneity, PMG is a consistent and efficient estimator.

The assumption underlying the PMG is that the error term, e_{it} is uncorrelated and also independently distributed and that implies that the regressors are exogenously determined. Another assumption is that cointegration exists among both the dependent and independent variables. The condition that makes PMG applicable is that the variables must be integrated all at I(0), I(1), or a mixture of both.

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 3, Issue 1, Jan.-Feb. 2023, pp: 610-622 www.ijhssm.org

4.1 Data and Sources

The nature of data for this study is longitudinal comprising both time series and cross-sectional data for each country. The year span is from 1997 to 2021 for all the countries. Ten African countries sampled n this study include Algeria, Cameroon, Benin, Egypt, Ghana, Morocco, Nigeria, South Africa, Tanzania, and Kenya,Data on GDP growth rate was obtained from World Development Indicators of the World Bank database. Data on precipitation and temperature were sourced from Terrestrial Air Temperatureand Precipitation database, gridded monthly time series, while energy demand, CO2, and Agricultural Productivity were all sourced from World Development Indicators. Data on capital stock for physical capital and labour employed were obtained from Penn World Table International comparisons of production, income and prices.

V. Presentation and Discussion of Results

This section shows the presentation of the estimated models and their implication on the Gross Domestic Product of the various countries represented.

5.1 Unit Root Test

The panel data were tested for stationarity and the following results were obtained.

Table 5.1: Panel Unit Test Results

Panel unit root test: Summary							
At Level				At First Difference			
Variables	Levin, Lin & Chu t* P-value	Im, Pesaran and Shin W-stat P-Value	ADF - Fisher Chi-square P-value	Levin, Lin & Chu t* P-value	Im, Pesaran and Shin W-stat P-Value	ADF - Fisher Chi-square P-value	Order of Integration
LNAGRIP	0.0015	0.0001	0.0000	-	-	-	I(0)
LNCO2	0.0004	0.802	0.7963	0.0000	0.0000	0.0000	I(1)
LNCSTOCK	0.0000	0.2848	0.2614	0.0156	0.0015	0.0044	I(1)
LNLEMP	0.0003	0.6798	0.6909	0.0183	0.0002	0.0005	I(1)
LNPREP	0.0000	0.0000	0.0000	-	-	-	I(0)
LNTEMP	0.0013	0.0000	0.0001	-	-	-	I(0)

Source: Author-generated using eviews 10

To confirm if the method of estimation specified in section 4.0 is valid for the estimation, we carried out the unit root test using the specified test methods in table 5.1 and the result showed that three of the variables are integrated at level and the other three at first difference. This makes it logical to employ the Pooled Mean Group for the estimation of the parameters.

5.2 Pooled Mean Group Estimation Results

Model 4.6 was estimated and tables 5.2 and 5.3 were the outcomes of the estimation. The advantage of PMG is that it shows both the long run and short run model together and that shows whether the variables are cointegrated. The lag selection was automatically done and the AIC criterion was selected with a lag length of 4 for all the variables.

Table 5.2 is the long-run model that shows how precipitation, CO2, capital stock, temperature and labour employed affect the Gross Domestic Product in the various countries within the time specified. The result showed that all the independent variables are statistically significant in the long run in affecting the GDP of all the countries, with their probability values less than 5 per cent.

Table 5.2: Long run Model

Dependent Variable: D(GDPGR)				
Method: ARDL				
Variable	Coefficient	Std. Error	t-Statistic	Prob-value

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 3, Issue 1, Jan.-Feb. 2023, pp: 610-622 www.ijhssm.org

LNPREP	0.80010	0.31100	2.5727	0.0127
LNCO2	-2.836299	0.813358	3.487148	0.0006
LNCSTOCK	0.307992	0.091382	3.370375	0.001
LNTEMP	-0.20011	0.092133	-2.1797	0.0101
LNLEMP	7.089144	2.026212	3.498717	0.0006

Source: Author-generated using eviews 10

In the long run, the result showed that precipitation change by one unit will increase GDP by about 80 per cent, CO2 will reduce GDP by 283 per cent, the capital stock will increase GDP by 31 per cent, temperature increase by one unit will reduce GDP by about 20 per cent and labour employed will increase output by about 708 per cent. This finding is in support of the works of Gupta, et al (2020) and Nastis, et al (2012) on the negative effect of climate change on agricultural output and consequently GDP growth. The statistical significance of the dependent variables also connotes the causality among the variables. This result showed that in the long run, rainfall or precipitation has a positive and significant effect on GDP growth, when the temperature becomes too high, it can hamper productivity, especially in the agricultural sector. Carbon dioxide emissions can hamper productivity in the sense that it will affect both the human beings that are working and the agricultural land and products. These results are in agreement with the works of Khurshid, Fiaz, Khurshid and Ali (2022) and Bodjongo (2022), where it was pointed out that high temperature was good for cotton but could be hazardous to other crops.

The second model generated from the PMG is the short-run model with the long-run representation, referred to as the cointegrating variable. Table 5.3 showed that the requirements for cointegration are satisfied. The coefficient of the error correction term is negative and statistically significant at the probability value of less than 5 per cent. The coefficient showed that every distortion in the short run will be corrected in the long run towards the equilibrium at the speed of 71 per cent per annum. Most of the independent variables are not statistically significant in the short run jointly, except labour employed, lagged one period and temperature both current and lagged one period.

Table 5.3: Error Correction Model (Short run)

Dependent Variable: D(GDPGR)				
Method: ARDL				
Variable	Coefficient	Std. Error	t-Statistic	Prob-value
COINTEQ01	-0.71043	0.110704	-6.41739	0.0000
D(LNPREP)	-0.7856	3.859521	-0.20355	0.839
D(LNPREP(-1))	-2.51349	1.880706	-1.33646	0.1835
D(LNCO2)	3.494668	2.9656	1.178402	0.2406
D(LNCO2(-1))	8.116782	5.464981	1.485235	0.1396
D(LNCSTOCK)	1.403484	4.793292	0.292802	0.7701
D(LNCSTOCK(-1))	-1.31249	4.708372	-0.27876	0.7808
D(LNLEMP)	8.391375	11.58087	0.72459	0.4699
D(LNLEMP(-1))	44.06371	9.982667	4.414022	0.0000
D(LNTEMP)	3.10222	1.51240	2.05119	0.0014
D(LNTEMP(-1))	6.14350	2.81231	2.18450	0.0032
C	-62.28	10.25286	-6.07441	0.0000

Source: Author-generated using eviews 10

As a result of the long-run relationship existing among the variables, we can infer that all the variables can cause GDP, that is, causality runs from precipitation, carbon emission, capital stock, labour employed temperature to GDP growth both in the long run and cross-sectionally. A look at the

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 3, Issue 1, Jan.-Feb. 2023, pp: 610-622 www.ijhssm.org

individual country estimation showed that most of the independent variables exhibit a long-run relationship with the dependent variable. The only country that does not show cointegration among the variables in Nigeria. These findings corroborate the findings of Tetteh, Baidoo and Takyi (2022 and Ogbuabor and Egwuchukwu (2017).

Checking the effect of climate change on agricultural output from model 4.2, the PMG estimated model is presented in table 5.4. AIC lag selection criterion was chosen with a lag of 1 for all the variables. The table showed that precipitation, carbon emission and labour employed are statistically significant in affecting agricultural production in African countries. The result showed that a unit increase in precipitation will have a negative effect on agricultural output by about 72 per cent. Carbon emission increasing by one unit will also negatively affect agricultural output by about 15 per cent and labour employed increasing by one unit will increase agricultural output by 49 per cent. The result of the effect of precipitation on agriculture may be one of the main explanations for the effect of flooding on the agricultural sector, especially in flood-prone areas.

The variables all show a long run relationship with the cointegration coefficient is negative and statistically significant. The implication of this is that these explanatory variables have long-run causality on agricultural output.

Table 5.4: Long run model of Agric output

Dependent Variable: D(LNAGRIP)				
Method: ARDL				
Variable	Coefficient	Std. Error	t-Statistic	Prob. Value
LNPREP	-0.71769	0.374799	-1.91487	0.037
LNCO2	-0.14577	0.063927	-2.28027	0.0237
LNLEMP	0.49286	0.167007	2.951128	0.0036
LNCSTOCK	0.015643	0.015361	1.018372	0.3098
LNTEMP	0.2101	0.113245	1.78666	0.07132

Source: Author-generated using eviews 10

Model 4.3 was also estimated using PMG and the result is shown in table 5.5. The lag selection criterion was AIC with a lag length of 1 for all the variables. The long-run relationship showed that carbon emission and temperature are statistically significant in affecting energy demand in the long run. As carbon emission increases by a unit, the demand for energy increases by 48 per cent and that temperature increase makes the demand for energy rise by 48 per cent. The implication is that as temperature increases, more people demand cooling systems, such as fans, and air conditioners, and a very low temperature like in the temperate regions will also lead to demand for heating oil. This result agrees with the work of Cian and Wing (2014) that showed that residential and commercial houses require cooling systems in tropical regions while demand for heating oil increases in temperate regions. Furthermore, the finding of this work further confirms the general findings in the literature, especially the work of Scott and Huang (2008) that demand for energy resources generally increases when there is global warming that raises the temperature. An increase in Carbon emissions could trigger an increase in energy demand in several ways. When carbon is emitted, it generates heat that will cause an increase in cooling systems. Similarly, the more carbon is emitted, especially in cars and industrial generators, the more energy is demanded for the operation of mobility or industrial use. On the other hand, high energy demand would generate more carbon emissions. All the variables are cointegrated with the cointegration coefficient showing a negative sign and statistically significant. All the groups individually showed a long-run relationship among the variables.

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 3, Issue 1, Jan.-Feb. 2023, pp: 610-622 www.ijhssm.org

Table 5.5: Long-run model of Energy Demand

Dependent Variable: D(LNENGYDD)				
Method: ARDL				
Variable	Coefficient	Std. Error	t-Statistic	Prob. Value
LNPREP	-0.25347	0.280799	-0.90267	0.3679
LNCO2	0.485743	0.074589	6.512275	0.0000
LNLEMP	-0.28656	0.191814	-1.49395	0.1369
LNCSTOCK	0.026096	0.024442	1.067679	0.2870
LNTEMP	0.41010	0.113245	3.62110	0.0013

Source: Author-generated using eviews 10

Model 4.4 was also estimated using PMG with the outcome of the estimation shown in table 5.6. The lag selection criterion was AIC with a lag length of 3 for the dependent variable and 4 for all the independent variables.

Table 5.6: Long-run model of Labour employed

Dependent Variable: D(LNLEMP)				
Method: ARDL				
Variable	Coefficient	Std. Error	t-Statistic	Prob. Value
LNPREP	0.446483	0.019043	23.4456	0.0000
LNCO2	-0.210305	0.006547	-32.12142	0.0000
LNCSTOCK	0.016682	0.00463	3.603224	0.0005
LNTEMP	-0.511000	0.12324	-4.146400	0.0002

Source: Author-generated using eviews 10

Some of the independent variables are positively related to employment and statistically significant in affecting labour employment in all the countries in the long run. Carbon emission is negative to labour employed. The result showed that if precipitation increases by one unit, labour employed will increase by 45 per cent, if capital stock increases by one unit, labour employed will increase by 1.7 per cent but if the temperature increases by one unit, labour employed will reduce by 51 per cent. The rationale for this is predicated on the fact that, at a higher temperature, labour productivity is reduced, especially work that has to be done directly under the sun. This finding is consistent with the work of Kahn, Mohaddes, Ryan, Pesaran, Raissi and Yang (2019).

The rationale for the above sectoral analysis is to examine which of the sectors is more affected by climate change. Precipitation affects agricultural output more than all the other sectors under consideration. For instance, a unit increase in precipitation reduces agricultural output by about 72 per cent, especially in flood-prone areas. Even though the effect of precipitation on labour is positive, its effect is less than that on agricultural output.

Carbon emission affects energy demand more than the other sectors in the study. An increase in carbon emission leads to about a 49 per cent increase in energy demand. The effect on energy demand is the highest compared to other sectors under consideration in the study. The effect of temperature is highest on labour employed, because of the effect of temperature rise on productivity. When the temperature rises, it affects labour employed negatively by about 51 per cent, which is higher than the other sectors. The foregoing analysis implies that climate change affects different sectors of the economy differently.

VI. Conclusion and Policy Recommendations

This work has examined the impact of climate change on gross domestic product and employment level of ten African countries. It also examined the effect of climate change on some sectors, such as agricultural and energy sectors using Panel Autoregressive Lag model or Pooled Mean Group method of estimation. It was revealed

from the results that climate change elements considered, such as precipitation, temperature and carbon emissions, all have significant impacts on gross domestic product and they all have long run relationship with the gross domestic product and the implication of the long run relationship could be that there is a causal relationship between the independent variables and GDP. Individual groups results reveal similar relationships of the independent variables in the long run with GDP.

The results also revealed that precipitation, temperature, carbon emissions and capital stock also have long run relationship and significant effect on labour employed. In the same vein, individual groups results exhibit similar findings. It was also revealed that precipitationaffect agricultural sector more than energy sector while carbon emissions affect energy demand more than agricultural sector, although both carbon emissions and temperature are statistically significant in affecting energy demand.

From the above results the following policy implications and recommendations are put forward. i). Since it is not practically possible to control how much rainfall or sunshine, the only way to mitigate the negative effects on GDP is to develop adaptation mechanisms that will help forestall the negative effects on agriculture and labour demand in that sector. Some of these adaptations include, but not limited to, improved farming efficiency through genetic improvement that can make the crops resilient against harsh weather conditions, gradually displacing fossil fuel usage through energy efficient resources, sequestration of carbon emissions from soil and crops.

ii). Introduction and application of efficient management systems and agricultural ecological management systems, such as biodiversification, soil management, and water harvesting, will assist farmers to adopt and adapt technologies that are climate resistant. Any of the policy measures that can help boost agricultural output will end up improving labour employed in the farms and eventually reduce the effect of climate change on all the sectors of the economy.

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