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Climate Change Effects on Economic Growth: Mixed Evidence from Anglophone West African Countries

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Abstract

West Africa is vulnerable to the effects of climate change. This paper analyzed the impacts of climate change on economic growth in Anglophone West Africa with similar background, during the periods 1969-2016. Five growth model equations have been developed to incorporate climate change variables into the model. Panel data estimations such as Fixed Effect model, Random Effect model and Hausman test was used. The results generated, show that four equations required the use of fixed effect, the agriculture equation model required the use of the random effect model. In the fixed effect models, the results show that growth of human capital has a negative and significant impact on the growth rate of the Services and Manufacturing sectors. In Anglophone West African countries, the growth rate of the Agriculture sector, Manufacturing sector and temperature are all statistically significant and has negative impact on the growth rate of GDP. In the random effect model for Agriculture, the growth rate of rainfall has the highest impact on the growth of Agriculture in Anglophone West Africa than the impact of temperature on the region. Lack of sufficient rainfall reduces growth of the Agriculture sector. In relative terms, change in rainfall pattern is more harmful to Agriculture in comparison to the change in temperature in this region.

Keywords: Climate Change, Economics Growth, Fixed Effect Model, Random Effect Model, Hausman Test, Anglophone West Africa

1. Introduction

1.1 Geographical Background of Anglophone West Africa

Anglophone West Africa comprises of 5 (The Gambia, Ghana, Liberia, Nigeria and Sierra Leone) out of the 15 countries that make up the Economic Community of West African States (ECOWAS) i.e. one-third of the countries in the sub-region. These countries were former British colony except Liberia. All of them are located on the west coast of Africa along the Atlantic Ocean where their major seaports and capital cities are also located except Nigeria's capital city, thus making their capital cities and seaports prone to sea-level rise which is a long-term effect of climate change. The total landmass of Anglophone West Africa is 1,503,099 km^2, with a combined population of 246.51 million and an average population growth rate of 2.47% (Fage & McCaskie, 2019). All of these countries have high population density in their urban cities and towns because their rural communities in most cases lack basic social amenities and infrastructures. Anglophone West Africa is home to Africa most populous country Nigeria and the smallest country on mainland Africa The Gambia.

The topography of Anglophone West Africa is heterogeneously characterized by diverse terrain of flood plains, low land plains with dissected plateau, upland plateaus, coastal plains, hills, mountains, mangroves etc. All these countries have bountiful natural resources, Nigeria and Ghana have petroleum, Liberia and Sierra Leone have diamond and other precious mineral reserves, yet poverty is highly prevalent in these counties. In light of climate variability, the poverty rate in Anglophone West Africa will continue to increase if appropriate policies are not taken. The aforesaid counties are faced with various degrees of environmental challenges such as drought in the case of The Gambia and Ghana, dust storms in Liberia and Sierra Leone and flooding in parts of Nigeria (Central Intelligence Agency, 2019). Climate change will further exacerbate these environmental problems unless effective remedial measures are taken.

(Sylla, Nikiema, Gibba, Kebe, & Klutse, 2016), cited Padgham et al. 2015 they noted that West African countries have recorded in recent decades warming temperatures, which increased between 0.3°C and 1°C. On the precipitation front (Sylla et al., 2016), buttressed that precipitation tends to have increased in some parts of the Sahel by about 0.2-1.0 mm per day per decade. They pointed out that in general, the Sahel (which constitute The Gambia and parts of Nigeria) has experienced wetter conditions while a small part of the Gulf of Guinea (which comprise Ghana, Liberia and Sierra Leone) has recorded drier conditions in recent years. The foregoing is an indication of the erratic nature of climatic conditions in the sub-region. Which have serious repercussions on the inhabitance who directly or indirectly depend on the natural environment for their source of livelihoods.

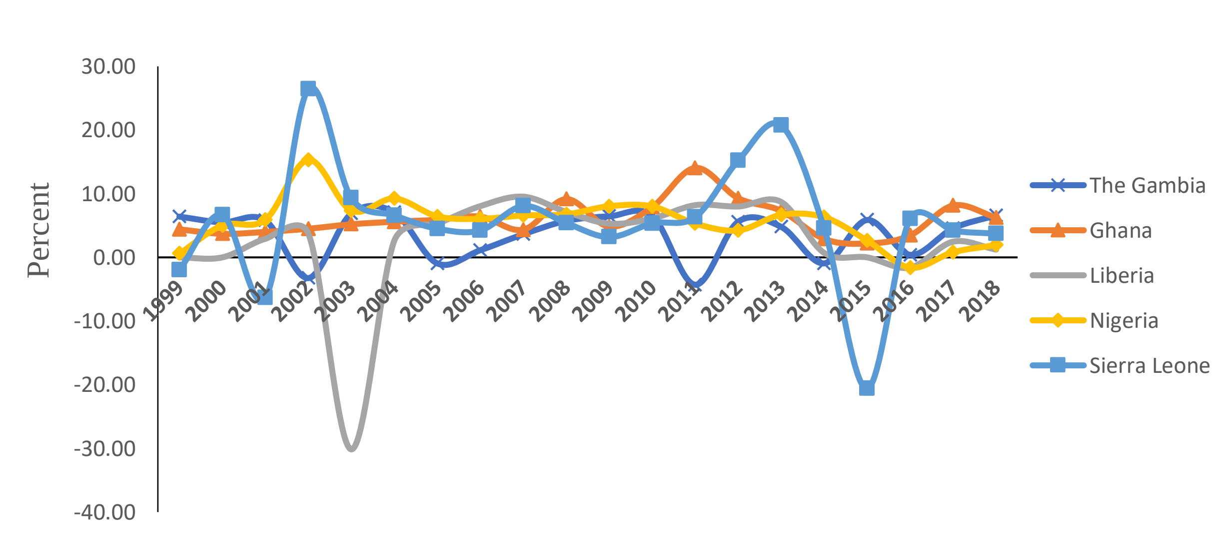
(Hartley et al., 2016), projected that the temperature in West Africa is expected to increase by 1.5°C to 4°C by 2050 especially in the Sahel compared to the Gulf of Guinea. On the precipitation side, they stressed that changes in rainfall are not as certain as temperature. In the Sahel, July to September by 2050 will be experiencing rainfall in the range of -40% to +20% in the western Sahel, and between -20% and +40% in the central and eastern Sahel. They also pointed out that there will be a delay of early raining season (June and July), particularly in the west of the Sahel, and an increase in late raining season (September and October), particularly in the central and eastern

Sahel. The Sahel projected rainfall uncertainty was also buttressed by (Serdeczny et al., 2016). This expected future situation will further aggravate the conditions of rural dwellers of Anglophone West Africa who depend on agriculture as their means of sustenance and income generation.

1.2 Economic Trends in Anglophone West African Counties

Figure 1 shows Gross Domestic Product (GDP) percentage growth for the past two decades in Anglophone West African countries, it could be observed that these countries experienced fluctuations in growth over the periods as a result of both internal and external economic shocks. Nigeria the biggest economy in the sub-region have not registered an impressive growth rate since 2015. In 2016 the Nigerian economic contracted to -1.6% due to attacked on petroleum facilities in the Niger Delta as a result in 2017 the country had a GDP growth of only 0.81%. Liberia and Sierra Leone have in the past decades been recovering from political and economic challenges that plagued their nations. In 2014 the outbreak of the Ebola disease in West Africa slowed their growth. By 2015 Liberia registered 0% growth and Sierra Leone contracted to -20%. However, both countries have seen a rebound in 2017 and 2018. The Gambian economy is showing signs of recovery after the political impasse in 2016. Ghana's GDP growth is showing signs of buoyancy in 2017 and 2018 (World Bank, 2019). Given the economic vulnerability of Anglophone West African countries its vital that policymakers are cognizance of the impact of climate change on growth since a larger number of dwellers of the sub-region depend on nature (climate) for their survival hence the motivation for the study.

Figure1: GDP Precentage Growth Rate in Anglophone West Africa



Source: World Bank -World Development Indicators. Authors' Computation

According to (African Development Bank Group, 2019), the Services sector of West Africa remains the dominant sector in value-added contribution to GDP, accounting for half of the region's GDP in 2018, which was the trend since 2015. Manufacturing accounts for a small share of industry and is limited to light processing of primary products and production of consumer commodities. The trend in Anglophone West Africa is reflective of the sub-region. In The Gambia, Ghana, Nigeria and Liberia the Services sector is the main driver of their economies, whilst for Sierra Leone agriculture is the main driver. Agriculture remains a vital sector contributing on average about 20% of GDP in Anglophone West Africa. In most of these countries, the Agriculture sector is the dominant employer, the sector is seen as the most vulnerable to climate change relative to other sectors. The Services sector will also be affected by climate change especially the tourism industry which is also vital in almost all Anglophone West African countries. (Nwamarah et al., 2012), pointed out that climate change will cost Africa about 3% of the continent's GDP valued at US $ 40 billion per annum, given that Anglophone West African countries are prone to the effects of climate change they will incur a share of this colossal amount which will divert resources need for development into combating climate change.

Table 1: Sectoral Composition of Value-Added Percentage GDP

Source: World Bank -World Development Indicators, Authors' Computation

Country	Sector (% of GDP)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
The Gambia	Agriculture, Forestry and Fishing	25.20	26.22	28.95	18.89	20.34	25.33	22.30	23.55	24.96	23.04
	Manufacturing	5.79	4.98	4.73	5.16	4.89	5.65	6.34	6.11	5.48	4.48
	Services	55.57	54.96	53.09	62.05	60.96	57.12	56.94	53.15	52.85	56.55
Ghana	Agriculture, Forestry and Fishing	29.41	30.99	28.04	23.66	22.13	20.45	20.00	20.25	20.98	19.70
	Manufacturing	7.54	6.77	6.39	6.42	5.66	11.75	11.33	11.37	11.12	10.89
	Services	46.17	47.94	48.18	45.84	47.58	39.15	36.11	39.54	43.09	42.35
Liberia	Agriculture, Forestry and Fishing	65.17	58.04	44.80	44.30	38.80	37.23	35.77	34.37	37.24	37.09
	Manufacturing	2.96	2.81	2.61	2.28	2.12	1.93	2.26	2.14	1.95	1.84
	Services	27.73	36.95	50.20	47.40	44.80	47.01	48.53	53.09	50.34	48.24
Nigeria	Agriculture, Forestry and Fishing	25.28	26.75	23.89	22.23	21.86	20.76	19.99	20.63	20.98	20.85
	Manufacturing	8.17	7.84	6.55	7.17	7.72	8.93	9.64	9.43	8.68	8.74
	Services	48.98	50.98	50.79	49.24	50.19	52.37	54.15	58.12	59.79	55.80
Sierra Leone	Agriculture, Forestry and Fishing	53.65	55.26	52.94	54.59	50.59	47.98	51.79	58.65	58.21	60.28
	Manufacturing	2.44	2.13	2.18	2.25	2.02	1.64	1.53	1.77	1.82	1.96
	Services	35.10	34.60	35.26	35.25	32.56	28.48	29.83	33.87	33.29	32.38

2. Brief Literature Review

(Sillah, 2016), assessed the economic impact of climate change on the Islamic Development Bank (IsDB) member states using cross-sectional data and concluded that an increase in CO_2 emission by 1% will result in a decline of real GDP by an average of 0.47% for the dataset. The study found that Sub-Saharan Africa (SSA) member states are the worse region affected by CO_2 emission, it should be noted that 3 out of the 5Anglophone West African countries are IsDB member. (OECD, 2015), noted that doubling CO_2 emission will cause GDP loss of about 0.6% to 4.4% by 2060. Consequently, it is vital for emitter of CO_2 to be cognizance of the indirect relationship between CO_2 emission and GDP growth.

Numerous studies have pointed out that an increase in temperature has an impact on growth. (Abidoye & Odusola, 2015), show that 1°C increase in temperature reduces GDP growth rate by 0.27%, they further narrated that the impact of climate change is not homogeneous across SSA. This is because SSA is diverse and countries have their unique geographic and atmospheric features as highlighted in the geographical background section of the paper. (Stern, 2007), further explained that an increase in temperature of 4°C and above will seriously affect global food production thus resulting in a decline in food crop yield, especially in Africa. The rise in temperature will have global ramifications but the severity of the problem will have a huge effect on Africa than other regions in terms of food security.

Studies on Africa's rainfall projections are less certain as explained earlier. (Pereira, 2017), noted that there is a mixed-signal of rainfall increases and decreases. Their study pointed out that rainfall projections for western Africa and the Sahel regions are made up of large uncertainties. (Coulibaly, Metuge, Erbao, & Bin, 2017) show how adverse effect of precipitation will affect Ivorian cocoa export revenue, some of our sample countries are neighbours to Ivory Coast i.e. Ghana and Liberia hence similar conditions may prevail. (Mehmood-ul-hassan & Leeuw, 2015), cited Niang, et al., 2014 who stressed that African farmers will be faced with the challenges of more erratic rainfall, more frequent and severe droughts in drylands and savanna areas. Thus, the change in weather patterns they noted will alter the timing and length of cropping seasons which will affect lives and livelihoods of inhabitances of those settlements in long-run.

(Bulut & Gürkan, 2017), buttressed the need for the development of new species using biotechnological approaches and drought resistance verities that will possess high water use efficiency characteristics. The foregoing according to their paper will make provision for future food production in light of climate change. (Abidoye & Odusola, 2015), suggested the need for Africa to use research and development for adaptive measures for the development of draught resistance crop varieties. Their study also stressed the need for the promotion of effective water resource management infrastructure to enhance Africa agriculture development for economic growth.

The implication of delay or inaction in implementing climate policy has serious consequences. (Luderer et al., 2013), noted that a delay in adopting comprehensive climate policies will result in not only higher costs for reaching a given climate target but also an increase of the lower level of climate targets achievable within the range of acceptable cost levels. This emphasized the urgent and immediate action necessary to reduce the higher cost of inaction or delay in acting. According to (OECD, 2015), if no policy actions are undertaken, the combined effect of the impact on global GDP is projected to decline by 1% to 3.3% by 2060. It is, therefore, imperative that the necessary policy measures are taken to lessen the cost of inaction or delay which will be colossal for SSA.

On the issue of inefficient climate mitigation policies (Mendelsohn, 2009), elucidated that the biggest threat climate change pose are not climate-related disasters, but rather aggressive and inefficient mitigation policies which could increase mitigation cost to US $28 trillion. (Stern, 2007), pointed out that inefficient mitigation policies could be costly to society, it can be 14 times higher than optimal mitigation costs. Hence, as demonstrated misguided inefficient climate change programs and policies will pose a serious threat to economic growth.

The threat of climate change in West Africa is aggravated by limited access, awareness of and education about family planning, especially in rural communities, thus contributing to a rapidly growing population in the region. Whiles food production has remained almost constant or increased slowly, therefore food production has not been able to keep up with population growth, resulting in a higher demand for and supply of imported food (Jalloh, Nelson, Thomas, Zougmoré, & Roy-Macauley, 2013). This situation has increased poverty and deprivation in the continent, hence hindering economic growth significantly in many countries in SSA.

(USAID, 2011), elucidated that due to climate change in West Africa 3 key sectors will be seriously affected: (1) Food Security will be a serious challenge by 2020, with a potential decrease of about 50% in yields from rain-fed agriculture. (2) The Health Sector will witness extreme weather events such as droughts, heatwaves and storms thus leading to an increase in the incidents of meningitis, malaria, and acute respiratory infections. (3) Water Resources will be affected by declines in rainfall, increases in temperature and more frequent droughts which will result in a decrease in surface and groundwater availability and accessibility causing loss of lives, decline in agriculture production and the few areas that will be exposed to flooding will experience health and sanitary problems coupled with dilapidated of infrastructures.

3. Theoretical Framework

The theoretical framework of the study follows a dual approach using enumerative and dynamic approaches to study climate change impact on economic growth in Anglophone West Africa. (Akram, 2013), cited Nordhaus, 1991; Cline, 1994 and Tol, 1995 noting that the enumerative approach mostly focuses on sectoral (agriculture, services etc.) impact of climate change. This approach is done by doing short-run analysis, it ignores intertemporal effects and sectoral linkages. Conversely, the Dynamic approach can use different accounting growth models to assess the effects of climate change on growth. (Akram, 2013), buttressed the assumption of constant savings rate using the dynamic approach, which has found that climate change has a negative impact on productivity and investment. Which in the long-run will cause capital stock, consumption per capita and aggregate demand to decline and eventually resulting in unfavourable GDP.

3.1 Theoretical Model

The production function is used as a model with climate change variables, which forms the baseline for the study. The theoretical underlining for introducing climate change variables into the growth accounting model is for the comprehension of the decomposition of the effects of variations in weather on economic growth.

We used the basic production function derivation as followed by (Dell, Jones, & Olken, 2008): with some modifications:

$$Y_{it=e^{\alpha T_{it}} A_{it} L_{it} K_{it}} \quad \ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

$$\frac{\Delta A_{it}}{A_{it}} = g_{i+\ \beta T_{it}} \ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Where Y is GDP, L is measure of population, K is measure of capital, A is technology and can be referred to as labour productivity and T is a measure of climate. Equation 1 illustrates the direct effects of climate on economic growth e.g. effects on labour productivity. Equation 2 illustrates the indirect (dynamic) effects of climate e.g. the effects of climate on other variables that indirectly impact GDP.

By introducing logs in equation 1 and differentiating with respect to time, we derived equation 3 below:

$$g_{it} =_{g_{i+(\alpha+\beta)T_{it}} + \alpha T_{it-1}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

Where g_{it} is the growth rate of output, direct effects of climate change on economic growth are accounted for by α and indirect effects are accounted for by β and finally, g_i is the fixed effects.

4. Methodology

The interest in the relationship between the growth rate of an economy and climate change (pollution, rainfall, temperature, degradation, deforestation, erosion etc.) has increased in recent decades. Empirically, several estimation techniques are used to address this important phenomenon. We used the panel data techniques such as fixed effect, random effect and dynamic panel such as system Generalized Method of Moments (GMM) and GMM differences. As mentioned in the theoretical model section, we developed the production function in which we incorporated climate change variables and determinants of a country's growth sector such as Agriculture, Services and Manufacturing sectors into the Cobb-Douglas production function with capital, labour and technology, which is fixed over time. The economic growth depends on the following variables in the models: population growth and population growth rate, human capital and human capital growth rate, rainfall and rainfall growth rate, temperature and the rate of growth in temperature. The sectors affected by climate change problems were also be regressed by their growth rate.

Furthermore, researchers' that used Cobb-Douglas production function is not limited to (Hall and Mairesse 1995) in which they added capital as another factor of production in the model.

The paper adopts a model by Mohamed Abdouli and Sami Hammami (2015). To set out the production function for climate change as follows:

$$Y = b^{\beta} K^{\tau} L^{\delta} CLM^{\varphi} e^{\varepsilon} AW^{\alpha} \text{……………………………..(4)}$$

Where Y is the GDP, A is a given technology which is fixed, CLM is climate change variables which are (Rainfall + Temperature), K is capital, L is labour, and W contains population, e is exponential, ε is the idiogratic error term, and τ, δ, φ are parameters which are proportion. We incorporate climate change variables into the model to account for endogenous growth theory developed by Romer (1958) in which he incorporated human capita into production function.

$$Y = b^{\beta} K^{\tau} L^{\delta} CLM^{\varphi} e^{\varepsilon} AW^{\alpha} \text{………………………(same as above)}$$

We divide both sides by population to account for per capita terms. The assumption is the production function is constant return to scale i.e. $\tau + \delta + \varphi + \alpha = 1 \leftrightarrow \tau = 1 - \delta - \varphi - \alpha$

$$\frac{Y}{L} = b^{\beta} A \left(\frac{K}{L}\right)^{\tau} \left(\frac{L}{L}\right)^{\delta} \left(\frac{CLM}{L}\right)^{\varphi} \left(\frac{W}{L}\right)^{\alpha} e^{\varepsilon} \text{…………………(5)}$$

Taking the natural logarithm of both sides of the equation:

$$\log(Y) = \log(b^{\beta} A) + \tau \log(K) + \alpha \log(W) + \varphi \log(CLM) + \varepsilon \log(e) \text{ ………….(6)}$$

Note: exponential and log cancel out and let's $\log(b^{\beta} A) = \beta_0$, the resultant equation is equation 7:

$$\log(Y) = \beta_0 + \tau \log(K) + \alpha \log(W) + \varphi \log(CLM) + \varepsilon \text{ ………………………..(7)}$$

Transforming equation 7, for the growth model at time t and individual I, we obtain the following model:

$$g(Y)_{it} = \beta_0 + \tau_{i1} g(K)_{it1} + \alpha_{i2} g(W)_{it2} + \varphi_{i3} CLM_{it3} + a_i + \varepsilon_{it} \text{ ………………(8)}$$

Taking the first difference or fixed effect transformation or within transformations, we obtain:

$$g(\bar{Y})_i = \beta_0 + \tau_{i1} g(\bar{K})_i + \alpha_{i2} g(\bar{W})_i + \varphi_{i3} \overline{CLM}_i + a_i + \bar{\varepsilon}_i \text{ ……………….(9)}$$

We arranged the like terms together and subtract equations (9) from (8) we obtain equation 10:

$$\ddot{Y}_{it} = \tau_{it} \ddot{K}_{it} + \alpha_{it} \ddot{W}_{it} + \varphi_{it} C\ddot{L}M_{it} + \ddot{\varepsilon}_{it} \text{ ………………..(10)}$$

This is the fixed effect transformation or within transformation. The unobserved factors in the model disappeared. This suggests that we should estimate the model by pooled Ordinary Lease

Square (OLS). The pooled OLS estimator i.e. based on time demeaned variables is called Fixed Effect Estimator or Within Estimator.

Assumption:

Cov$(\varepsilon_{it}, CML_{it}) = 0, uncorrelated\ with\ all\ explanatory\ variables\ in\ the\ model\ \forall\ RE$

Cov$(\varepsilon_{it}, CML_{it}) \neq 0$, Correlated with all the explanatory variables in the model $\forall\ FE$

We included the sectors that, may be affected by climate change i.e. Manufacturing, Services and Agricultural sectors.

The model takes the following form:

$$Y_t = \beta_0 + \beta_1 POP_{\ t} + \beta_2 HC_t + \beta_3 T_t + \beta_4 RF_t + \varepsilon_t \text{ ……………(11)}$$

In the log-log form we transformed the model as follows;

$$\text{Model5(LnGDP)}: \ln Y_t = \beta_0 + \beta_1 \ln POP_t + \beta_2 \ln HC_t + \beta_3 \ln T_t + \beta_4 \ln RF_t + \varepsilon_t \text{ ……(12)}$$

$$\text{Model4(Lnclm)}: \ln Yclm_t = \beta_0 + \beta_1 \ln HC_t + \beta_2 \ln M_t + \beta_3 \ln Ag_t + \beta_4 \ln S_t + + \varepsilon_t \text{…..(13)}$$

$$Ag_t = \beta_0 + \beta_1 POP_{\ t} + \beta_2 HC_t + \beta_3 T_t + \beta_4 RF_t + \varepsilon_t \text{ ………………….(14)}$$

$$\text{Model 1(LnA)}: \ln Ag_t = \beta_0 + \beta_1 \ln POP_t + \beta_2 \ln HC_t + \beta_3 \ln T_t + \beta_4 \ln RF_t + \varepsilon_t \text{ ………(15)}$$

$$M_t = \beta_0 + \beta_1 POP_{\ t} + \beta_2 HC_t + \beta_3 T_t + \beta_4 RF_t + \varepsilon_t \text{ ……………….(16)}$$

$$\text{Model 3(LnMN)}: \ln M_t = = \beta_0 + \beta_1 \ln POP_t + \beta_2 \ln HC_t + \beta_3 \ln T_t + \beta_4 \ln RF_t + \varepsilon_t \text{ …..(17)}$$

$$S_t = \beta_0 + \beta_1 POP_{\ t} + \beta_2 HC_t + \beta_3 T_t + \beta_4 RF_t + \varepsilon_t \text{ …………..(18)}$$

$$\text{Model 2(LnS)}: \ln S_t = = \beta_0 + \beta_1 \ln POP_t + \beta_2 \ln HC_t + \beta_3 \ln T_t + \beta_4 \ln RF_t + \varepsilon_t \text{…..(19)}$$

Where:

$Y_t = GDP\ growth$

$\ln Y_t = GDP\ growth\ rate$

$Ag_t = Agricultural\ Growth$

$\ln Ag_t = Agricultural\ growth\ rate$

$M_t = Manufacturing\ growth$

$\ln M_t = Manufacturing\ growth\ rate$

$S_t = Service\ growth$

$\ln S_t = Service\ growth\ rate$

4.1 Data and Data Sources

A brief description of the data, the name of the variables and data sources used in the study are presented in Table 2:

Table 2: Data Sources

Name of Variable	Source	Comment
GDP Current (US$)	World Bank, WDI	Current GDP
Human Capital (Proxy)	World Bank, WDI	Enrollment in Secondary School
Agriculture	World Bank, WDI	Agriculture value added in US $
Manufacturing	World Bank, WDI	Manufacturing value added in US $
Service	World Bank, WDI	Service value added in US$
Temperature	World Bank	Total Average Temperature
Rainfall	World Bank	Total Average Rainfall
Climate Change (RF +TEM)		Total Climate change Variable

Note: WDI= World Development Indicator, RF=Rainfall and TEM=Temperature

5. Discussion of Results

5.1 Descriptive Statistics

Table 3, contains the descriptive statistics of the study. The number of observations fluctuates overtime. We used panel estimation for Anglophone West Africa with similar CO_2 emission per capita and similar vulnerability to climate change. We logarithmized the variables to interpret them as elasticity or rate of change overtime. The change in the growth rate of the Services sector has the highest mean in comparison with the other 2 sectors. This means that the Services sector is the highest growing sector and therefore it contributes more to the growth of the observed countries. The second highest growing sector is the Agriculture sector, which is just 0.2 lower than the Services sector. This is not astonishing since the Agriculture and Services sectors play a vital role in sustaining the economies of Anglophone West Africa as shown in Table 1.

The natural logarithm of the GDP has the highest mean, followed by the growth rate of rainfall in the observed panel. The growth rate of climate change has negative mean and smallest volatility as measured by the standard deviation. The growth rate of human capital has a mean of about 3.18 with a standard deviation of about 0.62 far from the mean.

Given the erratic nature of rainfall and high temperature records, the aforesaid contributes to the Agriculture sector having a lower contribution to the growth of Anglophone West Africa. Due to high CO_2 emission per capita, the Manufacturing sector had the lowest mean. The growth rate of the manufacturing sector has the higher standard deviation compared to the Agriculture and Services sectors, its standard deviation is volatile and is close to the standard deviation of the growth rate of Agriculture and Services sectors combined.

Table 3: Descriptive Statistics

Variables	Observation	Mean	Standard Deviation
LnH	138	3.178522	0.615652
LnS	182	3.714403	0.356525
LnA	197	3.503667	0.3839572
LnMN	195	1.850174	0.6348749
LnRF	240	4.789997	0.4916931
LNGDp	209	22.0129	2.162124
Lnclm	199	-1.049777	0.252329

Sources: Authors' Computation using Stata 13

Where:

LnH=Growth rate of Human capita
LnS= Growth rate of Service sector
LnA= Growth rate of Agricultural sector
LnMN= Growth rate of Manufacturing sector
LnRF = Growth rate of Rainfall
LNGDp= Growth rate of GDP
Lnclm= Growth rate of Climate change

5.2 Correlation

Table 4 contains the correlation results, which illustrates the relationship between variables under investigation. The growth rate of rainfall is positively correlated with the growth rate of the Agriculture sector. Thus, In Anglophone West Africa more rainfall will result in greater Agriculture output thereby increasing the incomes of those dependent on agriculture for their livelihoods. The growth in temperature has a negative impact on the growth rate of rainfall, hence in Anglophone West Africa, as temperature increase rainfall will decrease over time.

The growth rate of climate change variables which combines both rainfall and temperature growth rate manifest a negative relationship with the growth of the GDP, therefore as climate change variables become worse or rises economic growth in Anglophone West Africa may contract. Thus, there exist an inverse relationship between climate change and growth.

The Services sector is negatively correlated with growth rate of the Agricultural sector, growth rate of rainfall and growth rate of GDP. In Anglophone West Africa as the Services sector grow the Agriculture sector will experience a decline. As we have observed earlier in Table 1 the Services sector is the dominant sector in almost all Anglophone West African countries performing better than all other sectors with the exception of Sierra Leone.

The growth rate of the Manufacturing sector negatively correlated with growth rate of rainfall. This implies that if the Manufacturing sector is thriving the Agriculture sector will not perform. Surprisingly, growth rate of temperature is positively correlated with growth rate of GDP and growth rate of GDP is weakly positively correlated with the growth rate of rainfall, this means in Anglophone West Africa the temperature does play a key role in economic growth than rainfall does.

Table 4. Correlation Of Variables

Variables	LnH	LnS	LnA	LnMN	LnTM	LnRF	Lnclm
LnA	0.0184	-0.5961	-				
LnTM	0.5035	0.2439	-0.2746	0.371	-		
LnRF	-0.0885	-0.4952	0.4650	-0.41	-0.7733	-	
LNGDp	.6870	-0.2320	-0.3544	0.6279	0.2662	0.0639	-0.1582
Lnclm	-0.2672	0.2159	-0.3227	0.2426	-0.0921	-0.1077	-

Source: Authors' Computation using Stata 13

5.3 Panel Unit Root Test

The questions that arise for panel unit root test (fisher type unit root test for the coefficients) based on the Augmented Dickey-Fuller tests. Does our data contain a unit root? How do we know the confidence level at which we can reject the null hypothesis or accept the alternate vice versa. For the growth rate of GDP - is that all panel does not contain a unit root. Given our results, we failed to reject the null hypothesis. Since all the values in this test for the growth rate of GDP are greater than 1%, 5% and 10%.

This means there is unit root in our panels under the given test condition (included panel time, trend and mean). This also answers the second question, because the p-value tells us at which level of significance to reject or accept the null hypothesis. Table 5, contains all the variables with corresponding t-ratios and p-values with drift and trend. There is no unit root for the growth rate of rainfall, we rejected the null hypothesis at 1%, 5% and 10%. The p-value is smallest and we reject the null hypothesis of no unit root in the panel.

Table 5: Panel Unit Root Test (Fish Test in the First Difference)

Variables	T-Ratios		P-Value	
	Drift	Trend	Drift	Trend
LnH	-3.4077	2.5093	0.0012**	0.9904
LnS	-3.4073	-0.0171	0.0010**	0.4932
LnA	-3.8000	-1.6581	0.0003***	0.0540**
LnMN	-4.1926	-0.3310	0.0001***	0.3715
LnRF	-12.4402	-8.8001	0.0000***	0.0000***
LNGDp	-1.5014	0.8013	0.0720*	0.7853
Lnclm	-6.9391	-1.9464	0.0000***	0.0307**
LnTEM	-4.7105	-11.0444	0.0000***	0.0000***

Source: Authors' Computation using Stata 13 *Notes:* * , ** and *** denote significance at 10%, 5% and 1% respectively

5.4 Estimation Results

We estimated the empirical model by using the growth rate of agriculture, services, manufacturing, climate change and GDP. The Hausman test was used for the five equations, which determined the selection of either Fixed Effect model or Random Effect model. In the Hausman test, the Chi-square test suggests the use of Fixed Effect model for the four equations i.e. model 2 to 5 and one equation for Random Effect model i.e. model 1. Meaning the error term is uncorrelated with explanatory variables in agriculture equation model.

Table 6: Hausman Test Results

Equations	Probability of Chi-square	Chi-square Statistic
Model 1(LnA)	4.22	0.5185
Model 2(LnS)	58.78	0.000***
Model 3(LnMN)	-10.13	0.000***
Model 4(Lnclm)	28.78	0.000***
Model5(LnGDP)	-236.66	0.000***

Sources: Authors' Computation using Stata 13

5.4.1 Fixed Effect Model

The fixed effect model results are contained in Table 7, the results show that the growth of human capital has a negative and significant influence on the growth rate of Services and Manufacturing while human capital have a positive impact and significant influence on growth rate of climate change variables. Human capital has significant and positive relationship with the rate of growth of GDP. Thus, strengthening the vital role of human capital to the growth and development of Anglophone West Africa.

In Anglophone West African countries, the growth rate of Agriculture, Manufacturing and temperature are all statistically significant on the growth rate of GDP. The temperature and Services sector have negative impacts on growth rate of GDP. The variable not significant and but positively impact on growth rate of GDP is the growth rate of rainfall. Hence astonishingly, as observed Agriculture is statistically significant on growth whilst rainfall is insignificant but rainfall is positive impact growth unlike Agriculture.

Agriculture and rainfall are least impact variables on growth comparison to human capital. The severe effect of climate change on Agricultural was done by Relly (1999), Mendelsohn and Dinar (1999). When we added rainfall plus temperature, as climate change variable the results indicates that the level of growth of GDP are statistically insignificant and positive with growth of GDP.

In the Service sector, rainfall is insignificant and but positively impact on Services. Temperature is significant in the Service sector model. In the Manufacturing sector model both rainfall and temperature are insignificant with negatively and positively impacting the Manufacturing sector respectively. Finally, Manufacturing, Agriculture and GDP growth rate are statistically significant with the growth rate of climate change variable in Anglophone West Africa. The results found out that GDP and Agriculture negatively impacted on the growth rate of climate change Anglophone

West Africa. Manufacturing and human capital are significant and have positive impact on the growth rate of climate change. Overall, only service sector is not significant but positively impact the growth of climate change.

Table 7: Fixed Effect Model Results

Variable	Model 2 (LnS)		Model 3 (LnMN)		Model 4 (Lnclm)		Model 5 (LnGDP)	
	t-ratio	P-value	t-ratio	P-value	t-ratio	P-value	t-ratio	P-value
	Std E	Coef	Std E	Coef	Std E	Coef	Std E	Coef
Constant	-0.38	0.707	0.99	0.32	1.93	0.057*	1.93	0.054*
	(3.98)	-1.50	(8.96)	8.92	(1.7)	3.28	(36.2)	69.79
LnH	-1.68	0.09*	0.101 (-2.3)	0.023*	2.42	0.018*	9.10	0.000***
	(0.05)	-0.08		-0.23	(0.1)	0.29	(0.35)	3.17
LnA	-7.70	0.000***	0.13 (-6.9)	0.000***	-2.65	0.010*	-2.65	0.008**
	(0.06)	-0.44		-0.94	(0.2)	-0.42	(0.77)	-2.04
LnMN	-3.43	0.001***			2.25	0.027*	4.63	0.000***
	(0.04)	-0.15			(0.1)	0.18	(0.39)	1.82
LnRF	1.03	0.31	-1.11	0.268			1.32	0.185
	(0.12)	0.12	0.26	-0.299			(0.73)	0.96
LnTEM	1.74	0.09*	0.13	0.89			-1.70	0.089*
	(1.18)	2.05	(2.71)	0.36			(10.4)	-17.70
LnS			-8.96	0.000**	0.37	0.712	-0.15	0.883
			(0.18)	-1.62	(0.2)	0.064	(0.95)	-0.14

Sources: Author Computation using Stata 13, standard errors between parentheses * p=0.10, ** p=0.05, *** p=0.01

5.4.2 Random Effect Model

The results based on the Hausman test suggest that Random Effect model is more appropriate than Fixed Effect model in the case of the model growth rate of Agriculture. In Table 8, the results revealed that the growth rate of the Services sector and growth rate of the Manufacturing sector are highly significant and negatively impact on the growth rate of the Agricultural sector. The growth rate of human capital is moderately statistically significant and negatively affect the growth rate of the Agriculture sector. As growth rate of human capital increase by 1%, the growth rate of Agriculture reduces approximately 0.089%. Thus, in Anglophone West Africa human capital investment have an inverse relationship with Agriculture output. This phenomenon is also true for growth rates in both the Services and Manufacturing sectors.

The growth rate of temperature and rainfall are statistically insignificant and but associated positively and negatively on the growth rate of the Agriculture sector respectively. The growth rate of rainfall has highest impact on the growth of Agriculture in Anglophone West Africa than the impact of temperature. Lack of sufficient rainfall reduces the growth of Agriculture. In relative terms, change in rainfall pattern is more harmful to the Agriculture sector in comparison to the change in temperature in this region.

Table 8: Random Effect Model Results

Variable	Model 1(LnA)	
Dependent variable LnA	z-ratio	P-value
	Std E	Coef
Constant	0.27	0.78
	(4.73)	1.30
LnH	-1.98	0.05*
	(0.04)	-0.09
LnS	-11.02	0.000***
	(0.08)	-0.918
LnMN	-10.67	0.000***
	(0.03)	-0.37
LnRF	-0.38	0.70
	(0.09)	-0.04
LnTEM	1.52	0.129
	(1,35)	2.04

Sources: Author Computation using Stata 13, standard errors between parentheses * p=0.10, ** p=0.05, *** p=0.01

6. Conclusion and Policy Recommendation

This research attempts to explain the impact of climate change on growth in Anglophone West African countries with similar CO_2 emission per capita and vulnerability to climate change. The results generated shows, that the Agriculture sector is affected negatively by rainfall. Growth rate of rainfall has the highest impact on the Agricultural sector than temperature has in this sector. In relative terms, Manufacturing, Agriculture and GDP growth rate are statistically significant with the growth rate of climate change variables in Anglophone West Africa. The growth rate of Agriculture sector, Manufacturing sector and temperature are all statistically significant with GDP growth rate whiles growth rate of Services sector, Agriculture sector and temperature have negative impact on the growth rate of GDP. Rainfall growth rate is not significant but positively impact on growth rate of GDP.

We hereby make the following policy recommendations in light of the results generated from the study:

1. Anglophone West African countries should endeavor to legislate laws that will prohibit human activities that will result in decline in rainfall in the region since changes in rainfall has the highest impact on the Agricultural sector.
2. Governments in Anglophone West Africa must device policy that will continuously boost the Manufacturing sector since the sector have a positive impact on economic growth in the region.
3. Given that climate change variables negatively impact of agriculture growth on as manifested by the results of the study, Agriculture experts should proffer solutions to remedy the aforesaid situation.
4. It is vital for the growth and development Anglophone West Africa that governments continue to invest in the human capital since there exist a significant and positive relationship between human capital and the rate of growth of GDP.
5. To alleviate poverty in the region Anglophone West Africa governments should formulate policies that will reduce the vulnerability of the Agriculture sector to climate change given the inverse relationship that exist between climate change and the Agriculture sector.

References

Abidoye, B. O., & Odusola, A. F. (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

African Development Bank Group. (2019). *West Africa Economic Outlook 2019*. Retrieved from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/2019AEO/REO_2019_-_West_africa.pdf

Akram, N. (2013). Is Climate Change Hindering Economic Growth of Asian Economies? *Asia-Pacific Development Journal*, *19*(2), 1–18. https://doi.org/10.18356/e7cfd1ec-en

Bulut, H., & Gürkan, H. (2017). *Drought Stress Due To Climate Change*. (February).

Central Intelligence Agency. (2019). World — The World Factbook - Central Intelligence Agency. Retrieved August 31, 2019, from https://www.cia.gov/library/publications/resources/the-world-factbook/geos/xx.html

Coulibaly, S. K., Metuge, T. M., Erbao, C., & Bin, Z. Y. (2017). *CLIMATE CHANGE EFFECTS ON COCOA EXPORT: CASE STUDY OF COTE D'IVOIRE*. 200.

Dell, M., Jones, B. F., & Olken, B. A. (2008). *CLIMATE CHANGE AND ECONOMIC GROWTH: EVIDENCE FROM THE LAST HALF CENTURY*. *23*(5), 377–381. https://doi.org/10.1080/13504851.2015.1076141

Fage, J. D., & McCaskie, T. C. (2019). Western Africa | region, Africa | Britannica.com. Retrieved August 30, 2019, from https://www.britannica.com/place/western-Africa

Hall, B. H., & Mairesse, J. (1995). *Exploring The Relationship Between R&D and Productivity in French Manufacturing Firms*.

Hartley, A., Rowell, D., Janicot, S., Guichard, F., Macadam, I., Taylor, C., & Parker, D. J. (2016). *AFRICA'S CLIMATE HELPING DECISION-MAKERS MAKE SENSE OF CLIMATE INFORMATION*.

Jalloh, A., Nelson, G. C., Thomas, T. S., Zougmoré, R., & Roy-Macauley, H. (2013). West African Agriculture and Climate Change. *IFPRI*. https://doi.org/10.1038/154072a0

Luderer, G., Pietzcker, R. C., Bertram, C., Kriegler, E., Meinshausen, M., & Edenhofer, O. (2013). Economic mitigation challenges: How further delay closes the door for achieving climate targets. *Environmental Research Letters*, *8*(3). https://doi.org/10.1088/1748-9326/8/3/034033

Mehmood-ul-hassan, M., & Leeuw, J. De. (2015). *Enhancing the quality of African climate change science by investing in peer review capacity*.

Mendelsohn, R. (2009). *Climate Change and Economic Growth Commission on Growth and Development*. 60. Retrieved from www.growthcommission.orgcontactinfo@growthcommission.org

Mohamed, A., & Sami, H. (2017). Exploring Links Between FDI Inflows, Energy Consumption, and Economic Growth: Further Evidence from MENA Countries. *Journal of Economic*

Development, *42*(1), 95–117.

Nwamarah, U. U., Balgis, O.-E., Bahri, A., Theriault, K., Ngomba, C. M., Duru, U., … Jehu-Appiah, C. (2012). Solutions for a Changing Climate: The African Development Bank's Response to Impacts in Africa. *African Development Bank*, 8.

OECD. (2015). The Economic Consequences of Climate Change. In *The Economic Consequences of Climate Change*. https://doi.org/10.1787/9789264235410-en

Pereira, L. (2017). Climate Change Impacts on Agriculture across Africa. In *Oxford Research Encyclopedia of Environmental Science*. https://doi.org/10.1093/acrefore/9780199389414.013.292

Romer, A. S. (1958). Tetrapod Limbs and Early Tetrapod Life. *Evolution*, *12*(3), 365. https://doi.org/10.2307/2405858

Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., … Reinhardt, J. (2016). Climate Change Impacts in Sub-Saharan Africa: From Physical Changes to their Social Repercussion. *Springer*, *15*(February), 7–8. https://doi.org/10.1007/s10113-015-0910-2

Sillah, B. (2016). Economic Impacts of Climate Change: Evidence from OIC Member Countries. *Journal of Economics and Development Studies*, *5*(4). https://doi.org/10.15640/jeds.v5n2a6

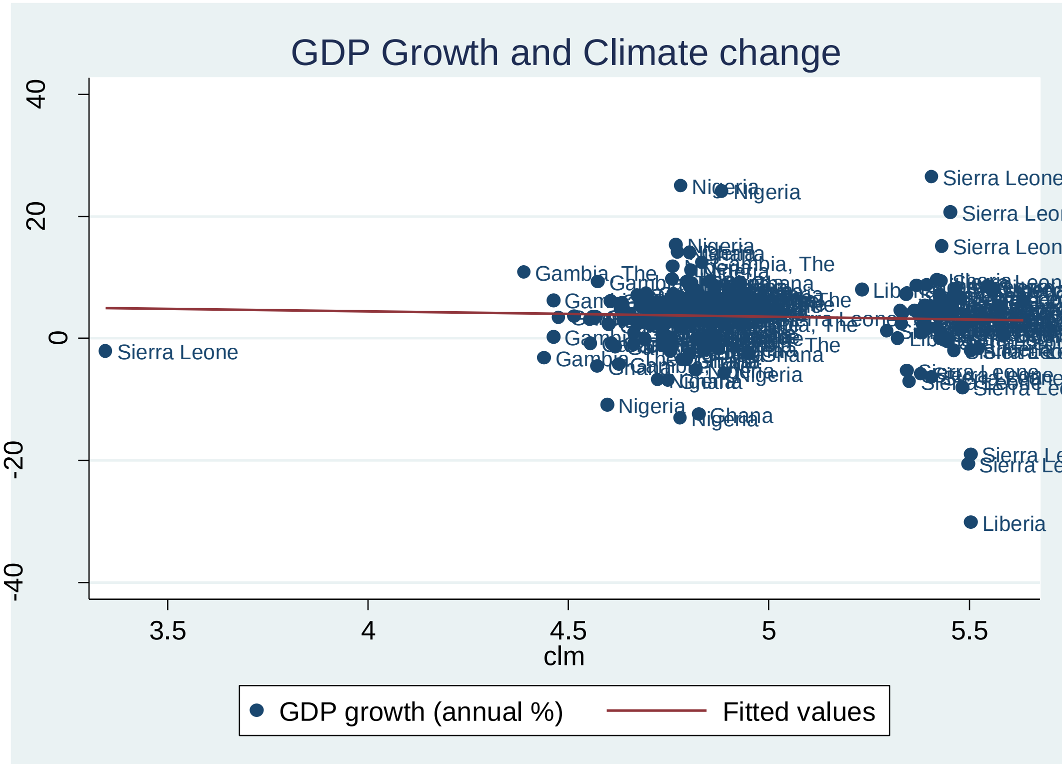
Stern, N. (2007). The economics of climate change: The stern review. *The Economics of Climate Change: The Stern Review*, *9780521877*, 1–692. https://doi.org/10.1017/CBO9780511817434

Sylla, M. B., Nikiema, P. M., Gibba, P., Kebe, I., & Klutse, N. A. B. (2016). Climate Change over West Africa: Recent Trends and Future Projections. *Adaptation to Climate Change and Variability in Rural West Africa*, (November 2017), 1–244. https://doi.org/10.1007/978-3-319-31499-0

USAID. (2011). *Climate Change Adaptation in WESTERN AFRICA Climate Change Adaptation in WESTERN*.

World Bank. (2019). World Development Indicators | DataBank. Retrieved August 31, 2019, from https://databank.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG/1ff4a498/Popular-Indicators

Appendix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-40
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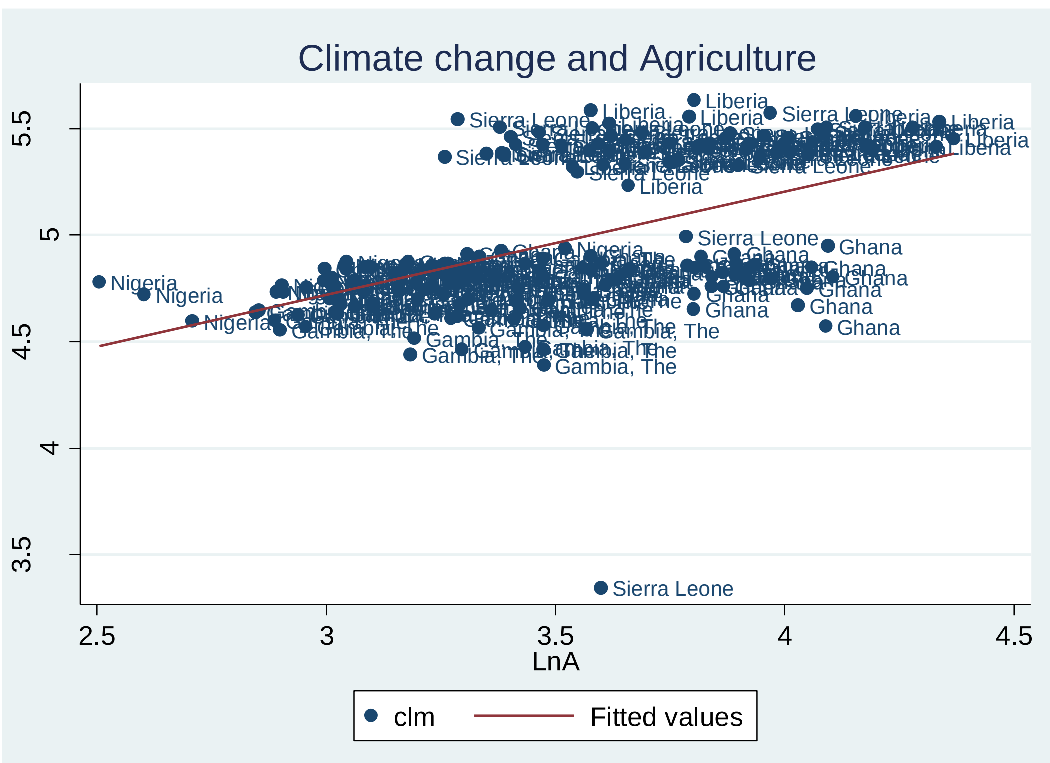
4
4.5
5
5.5
clm
GDP growth (annual %)
Fitted values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4.5
LnA
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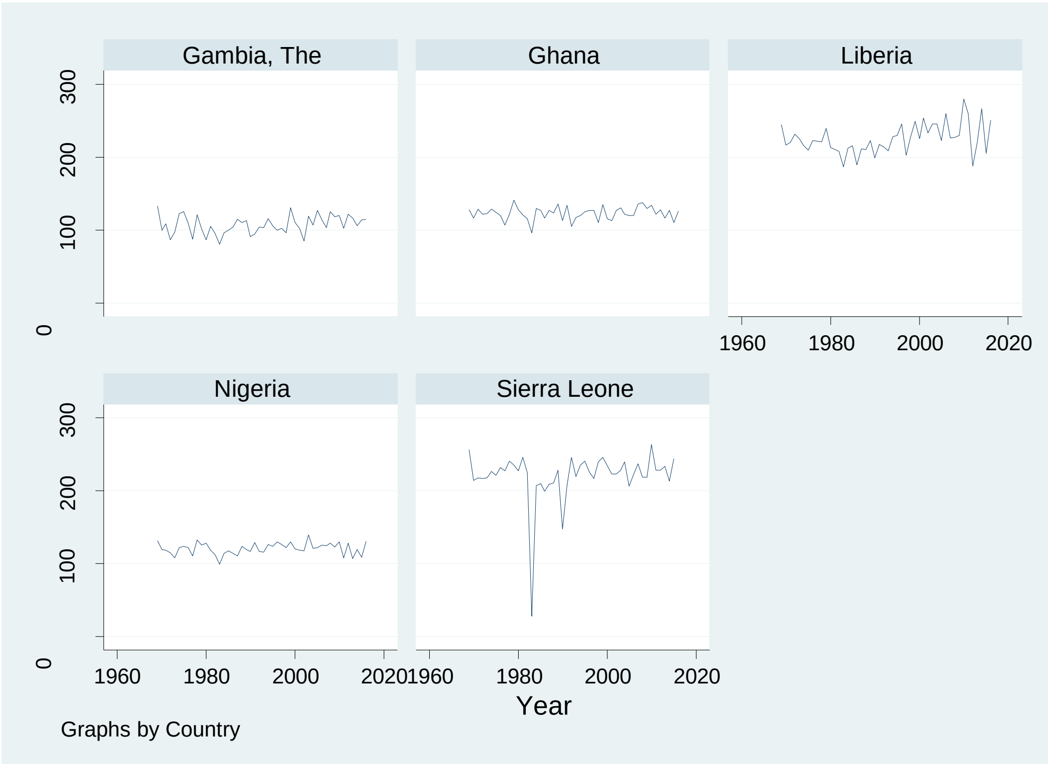
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Liberia
Nigeria
Sierra Leone
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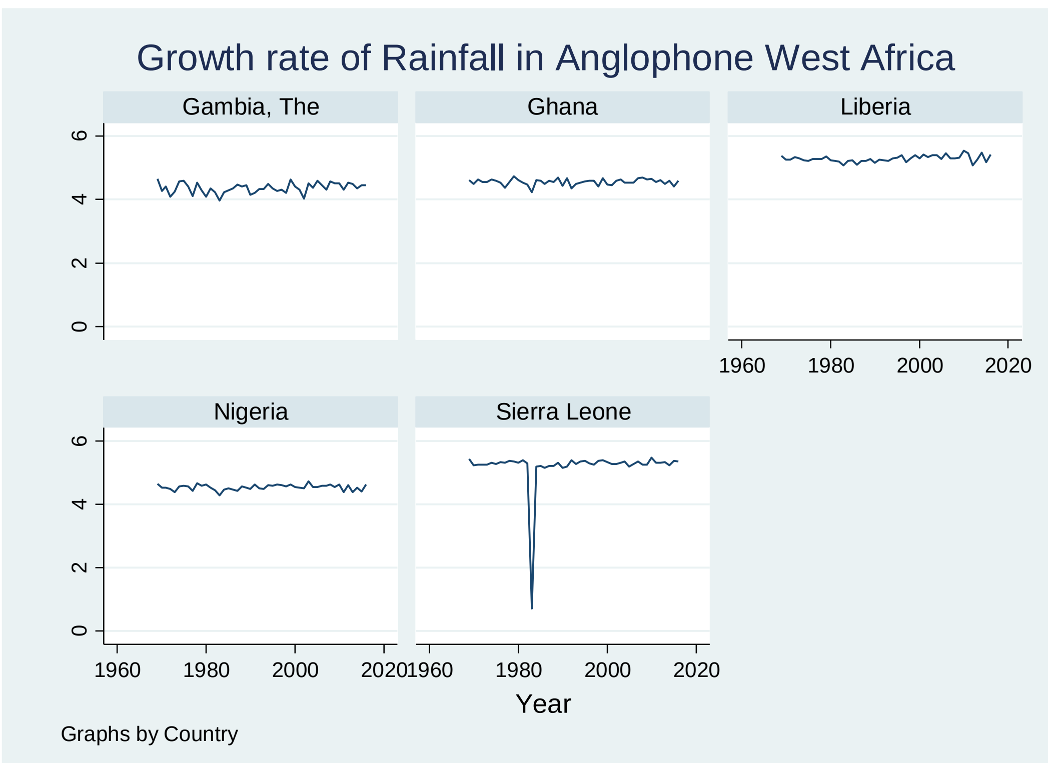
100
200
300
1960
1980
2000
2020
Year
Graphs by Country


Growth rate of Rainfall in Anglophone West Africa
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Liberia
Nigeria
Sierra Leone
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6
1960
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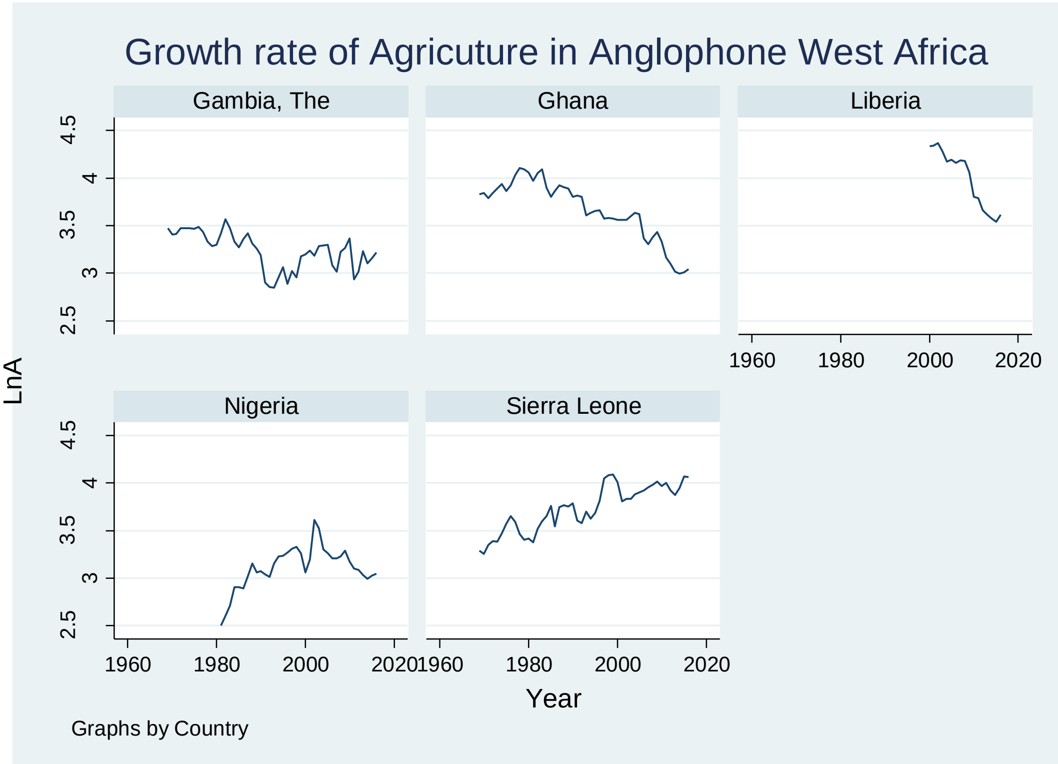
2000
2020
Year
Graphs by Country



Growth rate of Agricuture in Anglophone West Africa
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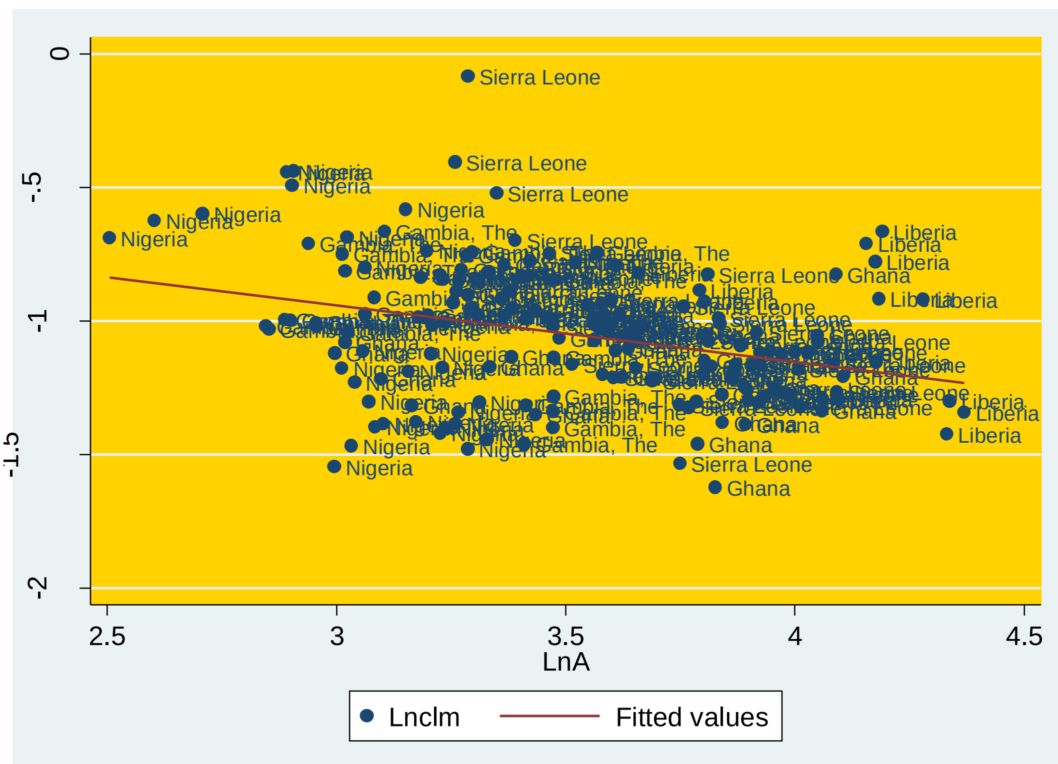
Liberia
Nigeria
Sierra Leone
LnA
Year
Graphs by Country



LnA
Lnclm
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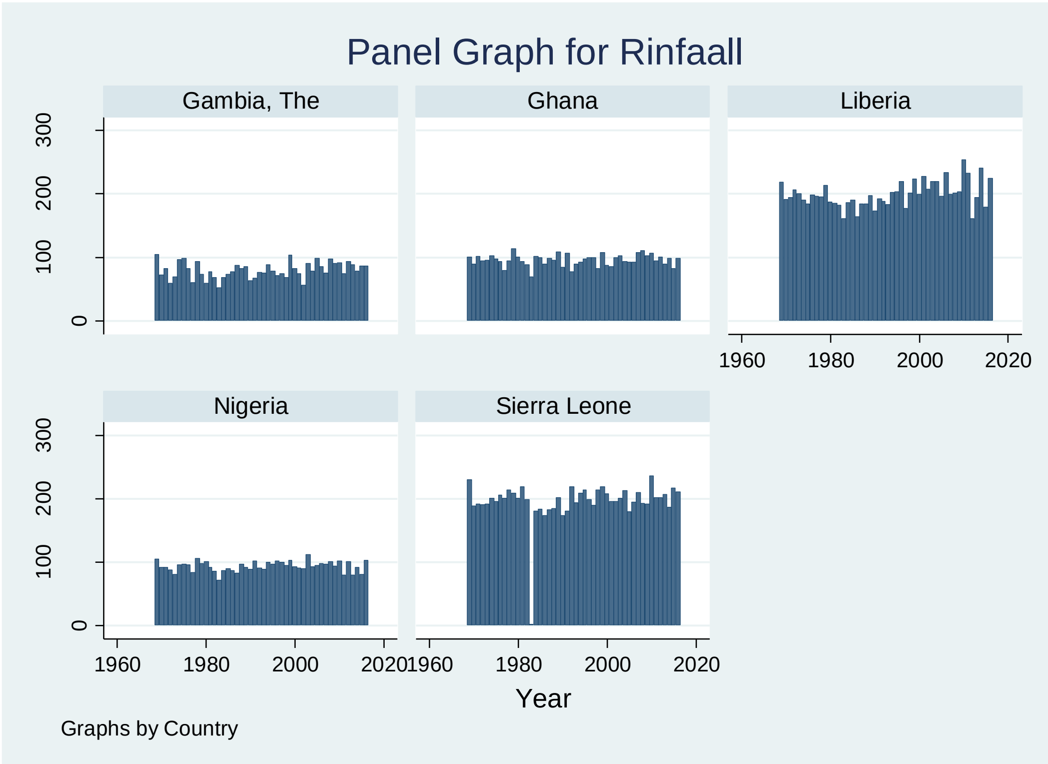
Panel Graph for Rinfaall
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Liberia
Nigeria
Sierra Leone
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1980
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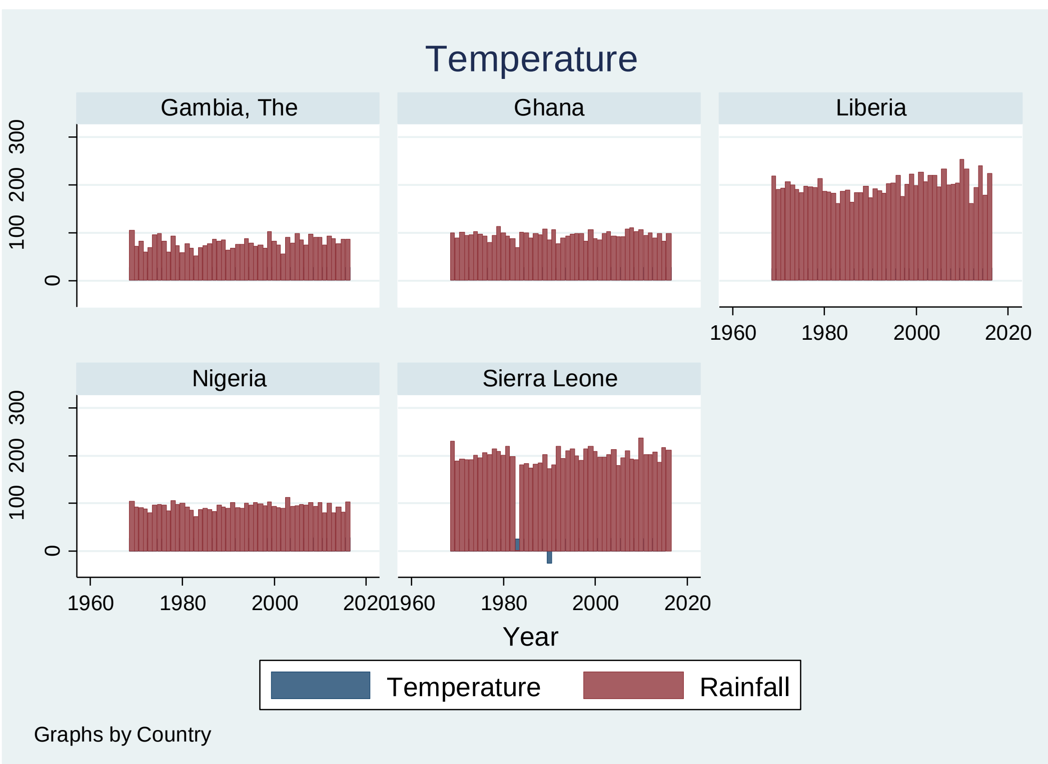
2020
Year
Graphs by Country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Gambia, The
Ghana
Liberia
Nigeria
Sierra Leone
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100
200
300
1960
1980
2000
2020
Year
Temperature
Rainfall
Graphs by Country