International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

The impact of climate change on economic growth based on time series evidence, 1969-2016

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ARTICLE INFO

Article History:
Received 09 June 2020
Revised 10 August 2020
Accepted 14 August 2020

Keywords:
Climate Change
Stationarity
The Gambia
Vector Autocorrection
Vector Error Correction

ABSTRACT

BACKGROUND AND OBJECTIVES: Climate change is one of the existential threats of modern times, which deserves urgent attention by policymakers. The objective of this paper is to comprehend the impact of climate change on the Gambian economy both in the short and long-run.

METHODS: This paper analyses time series data from 1969 to 2016. The study incorporated rainfall and temperature as proxies of climate change into the Cobb-Douglas production function. The Augmented Dickey-Fuller and the Phillips-Perron stationarity test for unit root found that the growth rate of rainfall is not statistically significant with the Mackinnon approximate p-value for z (t) =0.2306. The first lag is significant at 5% and 10% but has a negative coefficient in the first differential up to the fourth lag. In contrast, the growth rate of temperature is statistically significant with a p-value of 0.0196.

FINDINGS: The findings revealed that human capital growth is not significantly related to economic growth in The Gambia. In the long-run, the growth rates of climate change variables are all statistically significant and associated with a negative impact on economic growth. For the short-run, the lag difference of rainfall against its own lag is statistically significant and has a positive impact on economic growth. The lag difference in the growth rate of the Gross Domestic Product is not statistically significantly related to the growth rate of rainfall.

CONCLUSION: The Gambia is vulnerable to climate change shocks, consequently climate change will negatively impact economic growth resulting in high unemployment, low productivity, and high poverty rate.

DOI: 10.22034/IJHCUM.2020.04.03

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
36	3	11

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Note: Discussion period for this manuscript open until January 1, 2020 on IJHCUM website at the “Show Article.

INTRODUCTION

Climate change is one of the greatest threats confronting humankind, which poses enormous challenges for human welfare and development. The scourge of climate change has resulted in the deterioration of economies, ecologies and standard of living globally. The Gambia, being one of the countries that is both economically and environmentally fragile, necessitated this study which assesses the impact of climate change on economic growth. Numerous factors trigger weather and climate variation as highlighted in the literature. Africa is becoming one of the fastest warming continents with several days being warmer. This phenomenon will result in the decline in crop yields; by 2020 to 2100 yield will reduce from 50% to 90% respectively, thus affecting Africa's food security by the end of the century (Wiebelt, 2011). Sub-Saharan Africa (SSA) has witnessed a rapid growth in average yearly temperature compared with the global average of 0.6°C-0.7°Cover the period 1951 to 2010; out of the 30 countries sampled 20 countries in SSA have mean temperature above the global average. The Gambia's observed surface temperature change averages 1°C, thus a warmer atmosphere in SSA will affect the lives and livelihoods of the region's dwellers (Brahmbhatt *et al.*, 2016). File and Derbile, (2020), buttress that the current generation in Ghana are more exposed to higher temperatures and stronger sunshine which have an impact on smallholder farmers thus affecting the livelihoods of inhabitants. This scenario is not farfetched since it reflects the Gambian situation. There is empirical evidence in Africa that shows an inverse relationship between temperature and economic growth, and hence a 1°C increase in temperature in Africa reduces Gross Domestic Product (GDP) in the continent by over 0.5%. Numerous studies project that Africa will be warmer over time and hence economies in Africa are expected to contract (Abidoye and Odusola, 2015). Abeygunawardena *et al.,* (2016) forecast that climate change will negatively impact the entire economies of poor counties causing a decline in growth. This situation will be further exacerbated by inappropriate adaptation techniques, thus diverting funds needed for development to combating climate change. Alehile (2018) found that in Nigeria temperature has an indirect relationship with GDP both in the short-run and long-run, whereas precipitation in the short-run has direct relationship GDP but in the long-run the relationship is inverse. Hence climate variables of temperature and rainfall may have differing relationships with economic performance in the short-run and long-run. In Ivory Coast N'Zué (2018) elucidates that climate change has no significant effect on economic performance, thus buttressing that precipitation effect on crop yields is both significant and positive; ultimately agriculture value-added contribution to GDP is also significant and positive. This means that Ivory Coast, from the aforementioned studies, has no significant economic vulnerability as a result of climate change. However, that is not the case for other countries in SSA. In a related study of 43 African countries shows that rainfall is closely correlated with GDP per capita; hence the study countries will economically benefit from an increase in rainfall (Olanrewaju, 2019). In Pakistan temperature has a significant effect on economic growth both in the short-run and long-run whereas rainfall has a positive but insignificant effect on growth in the short-run (Ali *et al*., 2019). In Malaysia there exists no short-run relation between climate variables and growth (Rahim and Puay, 2017), it could be observed there are variations on the impact of climate variables on GDP from various countries. There exist widely held belief that adaptation practices are the best mechanism of alleviating the negative effects of climate change on farmers, thus providing farmers with food and income security to ameliorate the costs (social and economic) of climate change (Marie *et al*., 2020). The adaptation cost of climate change in West Africa, given a conservative estimate of low-warming and high-warming scenarios, will be approximately 0.3% and 0.4% respectively of Gross Regional Product (GRP) (Baarch *et al.*, 2017). (Qaisrani, 2015), human capital (education and health) is affected by climate change where climate change is considered among the factors responsible for the spread and aggravation of some diseases. It also triggers water-borne diseases (diarrhea), vector-borne diseases (malaria and dengue), heat stress and malnutrition. Education is seen as a catalyst that strengthens social networks which may be crucial in times of environmental risks. Education alleviates people from environmental danger since the educated earn higher incomes, have better access to information and enjoy an improved standard of living. Numerous other studies enumerated the negative impact of climate change on Africa's agricultural production and food security; they include but not limited to the following studies (Ngaira, 2007; Ayanlade and Ojebisi, 2019; McCarl *et al*., 2016; Masipa, 2017; Berhe and Kidanu, 2020). Awojobi and Jonathan (2017) expound that climate change in Africa is not fallacious; thus provide tangible evidence of the havoc that climate events are causing to the environment and the livelihood for the continent dwellers.

The study was conducted in The Gambia in 2019.

MATERIALS AND METHODS

Geographical background of The Gambia

The Gambia is the smallest country in mainland Africa, with a total landmass of 10,120km^{2}and water area of 1,180 km^2. It is surrounded on the north, east and south by Senegal and on the west side by the Atlantic Ocean. The country is divided into north and south banks by the River Gambia (Forde *et al.*, 2019). The Gambia Bureau of Statistics (GBoS, 2013), population and housing census 2013 estimated the country's population at 1.8 million with an average growth rate of 3.3% per annum, thus making the country one of the most populous countries in SSA, given its meagre resources and high poverty rate. The topography of The Gambia is predominately characterized by dissected plateaus with sandy hills, sandstone plateaus and valleys. According to Jaiteh and Sarr (2011), the natural flora of the plateau areas is altered and utilized for the cultivation of crops, dwellings and collection of firewood fuel. The paper stresses that the plateau terrain is the epicenter for groundnut (The Gambia's main cash crop) production and coarse-grain (sorghum and millet) cultivation. This topography is useful for both agriculture and human habitation purposes; however, it is still vulnerable to the effects of climate variability thus the need to conserve and preserve its vital function for human survival. The paper further explains that the valley areas are found alongside the River Gambia, and are prone to seasonal flooding, making the soil poorly drained with high salinity content where only mangroves can thrive. Finally, they paper note that the sandstone plateau is mostly unfit for cultivation. The limited arable land of sandstone plateau is used for the cultivation of groundnuts. The looming climate change challenge will pose further constraints on arable land availability for food production, human dwelling and animal grazing. The Food and Agriculture Organization (FAO, 2017) buttresses that the future temperature and precipitation for The Gambia will change by 2030. (Fig. 1) shows projected changes (increase) in annual average temperature across the length and breadth of The Gambia, with Banjul registering a+1.5°C increase and the Upper River Region registering +2°C during the period

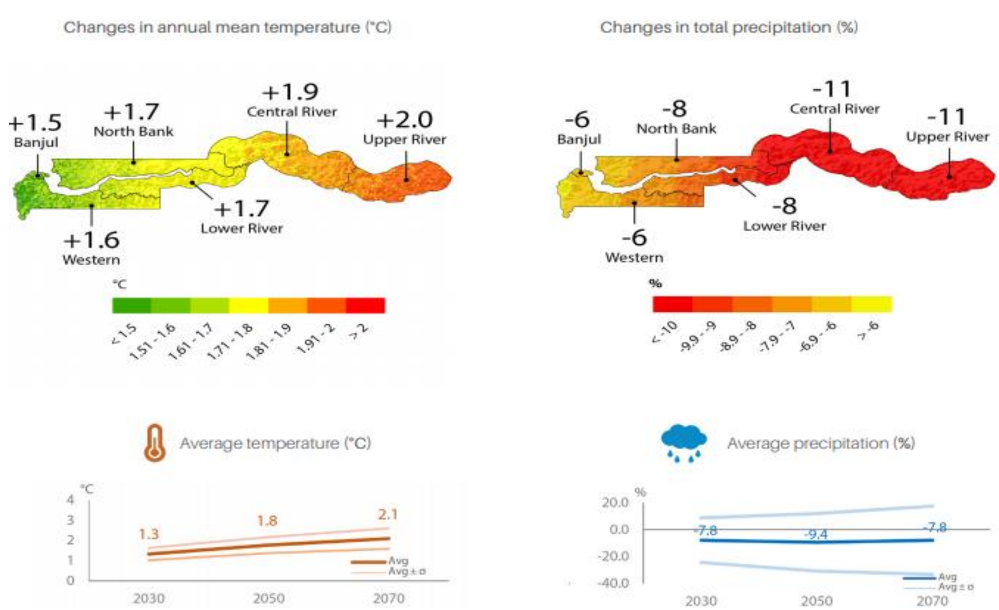


Fig. 1: Projected Changes in Temperature and Precipitation in The Gambia (FAO, 2017)

2030 to 2070. (Fig. 1)also shows projected changes (decrease) in total percentage precipitation across The Gambia with Banjul registering a-6% decrease and the Upper River Region registering -11% during the period 2030 to 2070. These projections are a real threat to agriculture and food security in the country in the future, thus illustrating the imminent dangers of climate change on human livelihoods.

The Gambian economy

The Gambian economy in 2018 showed signs of recovery following a sluggish performance in 2016 as a result of both internal (political impasse) and external (Ebola outbreak in some countries in West Africa) shocks. Real GDP estimates for 2018 were5.4% up from 3.5% in 2017. This growth was mainly driven by the services sector – tourism, trade and financial services and insurance. The fiscal deficit was slightly under control in 2018 - about 3.9% of GDP from 7.9% of GDP. Inflation decreased to an estimated 6.2% in 2018 from 8% in 2017 (ADB, 2019). Despite these modest macroeconomic gains, poverty, economic inequality and deprivation continue to be a challenge for The Gambia. According to The World Bank (WB, 2018), the most recent poverty study conducted in 2015/16 shows that the population living in poverty, based on the national poverty line, remained almost constant at about 47% to 48% from 2010 to 2015. The study shows that poverty in The Gambia is more pronounced in the rural communities. For the period reviewed rural poverty increased from 64.2% to 69.5% whilst urban poverty declined from 33.4% to 31.6%. From 2010 to 2015 extreme poverty increased by 17%. These facts are a manifestation of the severity of poverty in the country, which continues to be plagued with a high unemployment rate (50%) whilst youth unemployment is at a staggering 62%. 55% of the population in 2015 found it difficult or impossible to meet their daily required minimum calories of 2,400. These statistics could possibly aggravate the already dire situation if the country continues to experience erratic rainfall due to climate change. It is paramount that a small impoverished country like The Gambia understands the serious consequences of climate and weather variability on its future economic growth which is one of the motives for the study.

Other issues of climate change in The Gambia

Sea-level rise

(Serdeczny *et al*., 2016), study three cities in West Africa (Abidjan, Lomé, Lagos) and one city in Southeast Africa (Maputo), predicted that those cities will experience sea-level rise between 0.4 meters and 1.15 meters in a 4°C temperature increase world, and with a median rise of 0.65 meters. In a 2°C temperature increase world, sea-level rise is expected to be consistently lower, with a range of 0.2 to 0.7 meters and a median rise of 0.4 metres. The study is relevant in predicting how changes in temperature will impact on sea-level rise; is apt because a good

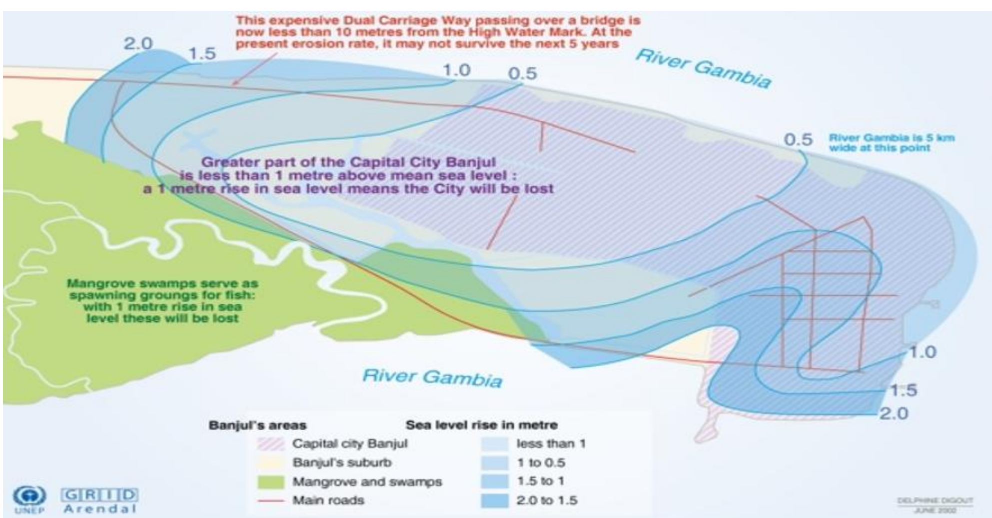


Fig. 2: Impact of Sea-level Rise in Banjul, The Gambia (UN Environment, 2019)

number of West African cities are located at the coastline of the Atlantic Ocean. A rise in sea-level without adaptation techniques will render some coastal cities and towns vulnerable, making them inhabitable in the long term. Banjul, the capital city of The Gambia, is not an exception. (Fig. 2) shows the expected sea-level rise in meters for various parts of the city of Banjul, and the impact of sea-level rise on the city, most parts of which are less than 1metre above sea-level. Therefore, a meter sea-level rise will result in the loss of Banjul and its suburbs. The only highway that links Banjul to other important towns will also be destroyed. Nearby mangrove swamps, which serve as spawning grounds for fish and other aquatic animals, will also be seriously affected (UN Environment, 2019).

Carbon emission

Loum and Fogarassy (2015) stress that carbon-dioxide (CO_2) is an essential element for plant development and also has a direct effect on crop productivity. At the same time, it serves as the catalyst for all climate change-related activities. There is strong evidence that the agriculture sector in The Gambia as a whole is vulnerable to climate change challenges. The paper scrutinizes historical data from 1960 to 2013 on climate change and crop production (maize and millet) which provided ample evidence that the effect of climate change on crop production in The Gambia could affect the food chain system which will have a multiplier effect on socio-economic development. Given the foregoing, it is important that effective measures are instituted to mitigate and combat the negative impact of carbon emission into the country's natural environment which has far-reaching consequences despite The Gambia being a relatively low carbon emitter. (Camara, 2013) points out that over 80% of The Gambia's estimated domestic energy is from biomass (fuel wood), emitting CO_2into the atmosphere during daily domestic food preparation. This report goes on to explain that the use of alternative energy like solar and wind could minimize CO_2emission into the atmosphere. The blueprint notes that efforts have been made to encourage Gambians to use efficient cooking stoves in order to conserve energy. In recent times the report points out that the country introduced a new biogas technology to replace fuel wood in some rural settlements. Such technology introduction in the rural and semi-urban settlements is vital to curb CO_2emissions, given that an overwhelming number of inhabitants of The Gambia use fuel wood to prepare their daily meals.

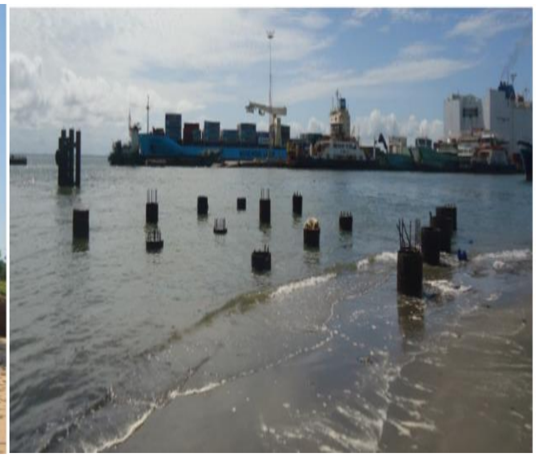
Economic impact of climate change

(Amuzu *et al.,* 2018), in a study on the socio-economic impact of climate change on the coastal zone of The Gambia point out that by the end of this century, given a scenario of a1metre sea-level rise, total land to be lost due to inundation will be 12.46 km^2 (1,246 ha) with an equivalent economic cost of US $788 million (GMD 37 billion) along the coastal zone of the country. According to the study, the land loss along the coastline of The Gambia will be due to coastal erosion, forecast to be annually approximately 6 meters. Such a situation will result in a number of inhabitants (15,560 persons per km^2) exposed to the risk of flooding and erosion. The study stresses that from Bald Cape to Solifor Point had the greatest area of land, 2.79 km^2 to be lost under scenario 1 metre sea-level rise, which is forecast to result in an economic loss of US $176.4 million. (Fig. 3) is an illustration of some of the economic damage/losses due to erosion. It is evident from this study that a poor resource constraint and an underdeveloped country like The Gambia does not possess affluence the wherewithal of combating climate change due to the fact that the economic impact of climate change is colossal. Funds that will be used to combat climate change and its impact could be used for much-needed social services and infrastructure development, hence the need for maximum precautionary measures to avert such expenditure.

Weak institutional and environmental regulatory framework

The Gambia's National Development Plan (NDP) 2018-2021 highlights the difficulties hindering sustainable environmental management, which is a consequence of poor institutional and regulatory frameworks coupled with the weak enforcement of current environmental legislation. The government blueprint buttresses the major factors affecting the environment: land degradation, coastal erosion, deforestation, biodiversity loss, ineffective waste and pesticide management. The development plan posits that deforestation through illegal logging and bushfires, sand mining, illegal settlements and other

(i) Old Wharf at the Banjul Port



(ii) Old Wharf at the Banjul Port

(iii) A Structure at Risk Due to Coastal Erosion

(iv) A Structure at Risk Due to Coastal Erosion

(v) Coastal Erosion along Kololi

(vi) Eroding Cliffs along the Coastline

Fig. 3: Some Images of Economic Damages/Loses Due to Erosion and Sea Level Rise (Amuzu *et al.,* 2018)

uncontrolled activities are the contributing factors of environmental degradation in the circumstances already made precarious by climate change. Hence the blueprint reiterates that the government will assess the NEMA Act, 1994 and strengthen the institutional and regulatory frameworks (Republic of The Gambia, 2018). Finally, the Republic of The Gambia, (2018) notes that "the impact of climate change has emerged as one of the most significant external factors hindering the performance of the growth-driving sectors, especially agriculture, tourism and industry, which have the greatest impact on the economy", hence the motivation for undertaking this study to analyse the impact of climate change on the economic growth of The Gambia in the short and long run. The finding will provide insightful information for policymakers and academics to understand The Gambian economy in light of the imminent threat of climate change.

Theoretical model

The paper adopts the theoretical concept of the production function by including climate variables into it as used by (Dell *et al.,* 2008; Bond *et al.*, 2010). Hence the growth accounting equation offers guidance for the decomposition of the impact of climate change on economic growth as derived below:

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

$$\frac{\Delta A_{it}}{A_{it}} = g_i + \beta T_{it} \quad (2)$$

Y is real GDP, L is labour force/population, A is technology and can also be referred to as labour productivity, K is human capital, T is the impact of climate, g is the growth rate of capital, t is time period and e is a constant. Eq. 1 captures the direct effects of climate on economic growth, e.g. the effects on labour productivity and Eq. 2 captures the indirect (dynamic) effects of climate, e.g. the effects of climate on other variables that indirectly impact on the GDP. Introducing logarithm into Eq. 1 and differentiating with respect to time, as derived Eq. 3:

$$g_{it} = g_i + (\alpha + \beta) T_{it} - \alpha T_{it-1} \quad (3)$$

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.

Data and data source

The data generated for this study were from the (WB, 2019), World Development Indicator (WDI). The period covered 1969 to 2016. The variables of interest are GDP growth rate, human capital, population density, temperature and rainfall as indicated in Table 1.

Economic model

Economic theory explains the behavior of one or more variables, say $Y_1, Y_2, Y_3, \ldots\ldots\ldots, Y_n$ as a function of some other variables, say $X_1, X_2, X_3, \ldots\ldots\ldots, X_m$ which are determined outside the model or which are exogenous in nature. Thus considering the following model: GDP growth as a function of population growth, climate change variables and human capita $Y = F(POP, CLM, HC)$, in which POP is population density, CLM is climate change variables, i.e. rainfall and temperature and HC is human capital.

Econometric model

The econometric model can be expressed thus:

$$Y = f(X_1, X_2, X_3, \ldots\ldots\ldots, X_k; \beta) + \varepsilon \quad (4)$$

β is a vector of unknown parameters and ε is the error term. The nature and the interpretation of

Table 1: Data and data sources

Name of Variable	Source	Comment
GDP Current(US$)	WDI	Current GDP US $
Human Capital	WDI	Secondary Enrolment
Rainfall	WB	Total Average Rainfall
Temperature	WB	Total Average Temperature
Population Density	WDI	Population Density

WDI= World Development Indicator

Eq. 4 depend on the assumption of the error term in the model. Therefore, (Eq. 5)

$$Y = \beta_0 + \beta_1 POP + \beta_2 HC + T\beta_3 + RF\beta_4 + \varepsilon \tag{5}$$

For this study of the impact of climate change on economic growth, secondary data was used. It is difficult to identify the economic linkages to climate change unless the use of sector performance variables like the agriculture, manufacturing and services sectors. Climate change variables like rainfall, temperature, marine resources, biodiversity, risk management, pollution, land degradation, deforestation, erosion, CO_2 emission affect the human ecosystem which in turn affects the economic growth of the country. In The Gambia, each of the aforesaid sectors is potentially affected by the interruption of climate change.

Time series analysis

Econometricians developed economic theory but no serious attempts are made to study the structure of the data. On the other hand, the time series analysis tried to allow the data to be modelled based on time intervals and to see whether the series is stationary at a certain point in time. According to Maddala (1992), the time series analysis is divided into two, i.e. frequency and time domain. This study uses time domain of time series analysis expressed as X_t.

Model specification

Research on the impact of climate change on economic growth is imperative, given the threat posed by climate change. However, limited research has focused on the subject matter in developing countries in recent times (Mendelsohn and Dinar, 1999). No study on the subject matter was done in The Gambia incorporating various economic models on climate change variables, hence the rationale for this study. The paper adopted the Solow and Romer model of production so as to determine the effect of climate change on growth in Real GDP. The focus is on output, capital, labour and the available technology. These factors of production combined to produce an output. The time series modelling of the variables is by lagged structure, the relationship between the series past, present and future values of y_t. The method involve is to fit the model as the Autocorrelation, Autoregressive Moving Average (ARMA), and Autoregressive Integrated Moving Average (ARIMA). Time series explains how current values depend on past values and their effect on future values of y_t . Hence, the data used was time series which applied unit roots and co-integration testing in order to estimate the long-run and short-run relationship. The unit root tests for the models used were the Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test, and apply co-integration test like, the Error Correction Model (ECM), the Vector Error Correction Model (VECM) and the Vector Autoregressive Model (VAR).

Unit root test

Co-integration test between the variables is stated in Eq. 6:

$$\hat{y} = \hat{\vartheta} + \hat{\pi} + \hat{\beta} x_t \tag{6}$$

The Dickey Fuller (DF) test for the residual $\hat{\varepsilon}_t$ is stated as:

$$\Delta Z_t = c + \beta Z_{t-1} + \sum_{i=1}^{T} \varphi \Delta X_{t-1} + \varepsilon_t \tag{7}$$

Symbol Δ in Eq. 7 is the first difference, which is always stationary, T is the optimal lagged structure for the model, φ_i is time-dependent, β is the rate of change of Z_{t-1}, c is the constant-coefficient and ε_t is the residual for ADF test at time t. The hypothesis testing for the unit root is that $H_0 : \beta = 0 vs. H_1 : \beta \neq 0$. The condition for the stationarity process is that the coefficient β is statistically significant, the hypothesis that Z_t contains unit root is not rejected and the alternative is rejected. To conduct the co-integration test in multivariate analysis the study used Johansen co-integration with maximum lag length structure. By considering K lags, a general VAR (K) model is formulated as shown in Eq. 8:

$$Y_t = c + A_t \sum_{t=1}^{K} Y_t + U + \varphi D_t + \varepsilon_t \tag{8}$$

$Y_t = a_n$ n by 1 vector I (1) process
A_t , t=1… k is n by n vectors
U Is a constant term
D represents vector dummies

ε Is a vector of normally distributed, iid with mean zero and variance square i.e. (0.1).

Simulating using VECM and ECM to capture the relationship between and among variables, the VECM is use as shown in Eq. 9:

$$\Delta Y_t = \omega Y_{t-1} + \theta_t \sum_{t=1}^{K} \Delta Y_t + U_t + \varphi D_t + \varepsilon_t \quad (9)$$

The long-run relationship is captured by the term ωY_{t-1} and θ_t is the short-run coefficient of shocks on ΔY_t. Which yields Eq. 10 below:

$$\omega = -(1 - \varepsilon A_i)\, and\, \theta_t = -(1 - \varepsilon A_j) \quad (10)$$

RESULTS AND DISCUSSION

Descriptive statistics

Table 2 contains descriptive statistics results. The descriptive statistics indicated that there are period gaps in the human capital data, hence the limited observations for human capital compared with other variables. The study logarithmized the variables to interpret them as a rate of change. The descriptive statistics contains the means and the standard deviations of the variables used in the study. The growth rate of GDP has the highest mean (19.733) and the highest standard deviation (0.985). This is the result of the spread of the data on the GDP; hence it has the highest volatility. The growth rate of human capital has the lowest mean (2.843); this is due to its limited number of observations compared with the other variables. However, it possesses the second-highest standard deviation (0.489). The variables with less volatility are the growth rate of temperature followed by the growth rate of rainfall as indicated by their standard deviation results of 0.017 and 0161 respectively.

Correlation

The correlation results illustrate the nature of the relationship that exists between the variables under study as shown in Table 3. The growth rate of population in The Gambia has a negative correlation with the growth rate of the GDP (-0.0092). This result was surprising, given the expectation that population growth will lead to the growth of GDP due to innovation and the discovery of new technology by the population. However, population density growth causes the GDP to increase drastically by approximately 93%. The growth rate of human capital has a strong positive relationship (83%) with the growth rate of the GDP. In the case of a change in temperature, an increase in temperature causes the GDP to increase approximately by 72% whilst an increase in rainfall leads to an increase in the GDP by approximately 19%. Hence the growth rate of temperature has a stronger degree of influence on the growth of the GDP than changes in rainfall in The Gambia.

Time series test

The data used in the model is time-series data.

Table 2: Descriptive statistics

Variables	Observation	Mean	Standard Deviation
LnGDp	48	19.73355	0.9853304
Lnh	29	2.843349	0.4892193
LnTM	48	3.320104	0.0176179
LnRF	48	4.365117	0.1619504
Lnpden	48	4.592953	0.4803583

LnGdp =Growth rate of GDP; Lnh= Growth rate of human capital;
LnTM= Growth rate of temperature; LnRF = Growth rate of rainfall;
Lnpden=Growth rate of population density

Table 3: Correlation of Variables

Variables	LnGDp	Lnh	LnTM	LnRF	LnPden
LnGDp	-	-			
Lnh	0.8332	0.7612	-		
LnTM	0.7276	0.7143	-	-0.17	
LnRF	0.1934	0.3013	-0.1718	-	
Lnpden	0.9332	0.9488	0.7565	0.2924	
Population growth (Annual)	-0.0092	-0.0785	0.0318	0.0165	0.0529

Computation using Stata 13

Preliminary tests were conducted before proceeding to conduct further estimation techniques. The tests include unit root tests of ADF and PP test and cointegration testing. In order to test the long-run and short-run dynamics relationship between the variables, VECM (Vector Error Correction Modelling) and VAR (Vector Auto regression) modelling were applied.

ADF test for unit root

Table 4 indicates the ADF test results for unit root test showing both the trend and constant have a positive slope and both are stationary at 5%. The results show that the lag of GDP is negative, but the mean, variance and covariance are stationary; however, its coefficient is positive for the lag of the first differential of the GDP. The results for the first differential are not statistically significant at 5% with stationarity at the lag length of four. For the growth rate of rainfall in Table 5 is not statistically significant for the Mackinnon approximate p-value for z (t) =0.2306. The first lag is significant at 5% and 10% but has a negative coefficient in the first differential up to the fourth lag. In contrast, the growth rate of temperature in Table 6 is statistically significant at a p-value of 0.0196. Human capital growth is not statistically significant in The Gambia according to the time series analysis.

Phillips-Perron test for unit root

The Phillips-Perron test for unit root is to modify the ADF by correcting any serial correlation, heteroskedasticity in the error term and in order to make robust the serial correlation, heteroskedasticity

Table 4: The ADF stationary test for the natural logarithm of GDP with trend and constant in The Gambia

Variables	Coef.	t-statistics	ADF/P-value	Results	Lag Length
Lag1(LnGDp)	-0.2388017	-2.57	0.014**	Stationary	4
1st Differential	0.0760815	0.50	0.623	Not Stationary	4
2nd Differential	0.1643747	1.06	0.294	Not Stationary	4
3rd Differential	0.187936	1.20	0.240	Not Stationary	4
4th Differential	0.0571842	0.33	0.741	Not Stationary	4
Trend	0.0133028	2.12	0.041**	Stationary	4
Constant	4.435275	2.64	0.012**	Stationary	4

Computation using Stata 13; * p=0.10; ** p=0.05; *** p=0.01

Table 5: The ADF stationary test for natural logarithm of rainfall with trend and constant in The Gambia

Variables	Coef.	t-statistics	ADF/P-value	Results	Lag Length
Lag1(LnRF)	-1.041604	-2.71	0.010**	Stationary	4
1st Differential	0.1147444	0.34	0.735	Not Stationary	4
2nd Differential	-0.017909	-0.07	0.948	Not Stationary	4
3rd Differential	-0.0690262	-0.3	0.754	Not Stationary	4
4th Differential	-0.0673283	-0.44	0.663	Not Stationary	4
Trend	0.0038512	1.59	0.120	Not Stationary	4
Constant	4.449262	2.72	0.010**	Stationary	4

Computation from Stata 13; * p=0.10; ** p=0.05; *** p=0.01

Table 6: The ADF stationary test for natural logarithm of temperature with trend and constant in The Gambia

Variables	Coef.	t-statistics	ADF/P-value	Results	Lag Length
Lag1(LnTM)	-1.266052	-3.74	0.001***	Stationary	4
1st Differences	0.2800077	0.92	0.362	Not Stationary	4
2nd Differences	0.2823839	1.07	0.290	Not Stationary	4
3rd Differences	0.2277942	1.18	0.246	Not Stationary	4
4th Differences	0.1991193	1.46	0.153	Not Stationary	4
Trend	0.001397	3.59	0.001***	Stationary	4
Constant	4.167695	3.75	0.001***	Stationary	4

Computation from Stata 13; * p=0.10; ** p=0.05; *** p=0.01

and autocorrelation consistent with the covariance matrix estimator. The results generated for both growth rate in rainfall and temperature show that all the coefficients and the intercepts are positively sloped and a lag of the growth rate of rainfall is not significant and the trend is significant at 5%, whilst the intercept is highly significant at 1% as indicted in Table 7. The Phillips- Perron test of change in temperature pattern in The Gambia is highly significant at a p-value of 0.0000; likewise the intercept, as shown in Table 8, human capital growth is not significant in The Gambia. This means a small country like The Gambia should invest in human capital to ameliorate the phenomenon of climate change.

Cointegration test

Applying the Varsoc to select the optimal lag length for the model, a maximum lag of 8 was selected. The exogenous variable is constant and the endogenous variables are LnGDp, LnRF, LnTM, Lnh, Lnpopdn, and the population growth rate. The cointegration equations were tested using Johansen tests for cointegration as shown in Table 9. Various kinds of tests were conducted for the selection of the maximum lag length for the model; the test included the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC) and the Hannan-Quinn Information Criterion (HQIC). Based on the aforesaid selection method, lag 4 was used. In addition, the optimal lag structure for the model was used in order to identify the Johansen cointegration equation and ranking for the model. The Johansen tests for cointegration indicated that the rank of the cointegrating model is 3, as seen in Table 9. For the Log-likelihood model, it is observed that population growth annually is highly significant and has a negative coefficient. The growth rates of climate change variables, i.e. temperature and rainfall growth, are also statistically significant and associated with a negative coefficient, as indicated in Table 10. Hence in the long run these variables will be statistically significant. The implication of the foregoing is that population growth, and changes (increase) in rainfall and temperature will have a negative impact on the growth rate of the GDP in The Gambia. In the short-run dynamic model in Table 11, the lag difference of rainfall against its own lag is statistically significant and has a positive relationship on economic growth. Lag difference in the growth rate of the GDP is not statistically significant against the growth rate of

Table 7: The Phillips-Perron test for stationary for rainfall with trend and constant in The Gambia

Variables	Coef.	t-statistics	ADF/P-value	Results	Lag Length
Lag1(LnRF)	0.0470148	0.33	0.741	Not Stationary	4
Trend	0.0036722	2.18	0.034**	Stationary	4
Constant	4.065723	6.67	0.000***	Stationary	4

Computation from Stata 13; * p=0.10; ** p=0.05; *** p=0.01

Table 8: The Phillips-Perron test for stationary for temperature with trend and constant in The Gambia

Variables	Coef.	t-statistics	ADF/P-value	Results	Lag Length
Lag1(LnTM)	0.1043908	0.76	0.449	Not Stationary	4
Trend	0.0009184	5.29	0.000***	Stationary	4
Constant	2.951304	6.55	0.000***	Stationary	4

Computation from Stata 13; * p=0.10; ** p=0.05; *** p=0.01.

Table 9: Johansen tests for cointegration

Max Rank	Log-likelihood	Eigen value	Trace Statistic	5% Critical Value
0	401.06254	-	87.6582	47.21
1	419.91639	0.55945	49.9505	29.68
2	433.1465	0.43742	23.4903	15.41
3	444.23093	0.38241	1.3215*	3.76
4	444.89166	0.02832	-	-

Computation from Stata 13; *Indicates that this estimator has a triple rank (r=3) cointegration equation

Table 10: Johansen normalization (Long-run model)

Variables	Coefficient	Standard Error	T- Statistic	P- Value
LnGDp	1			
Lnh				
LnTM	-41.62783	5.852506	-7.11	0.000***
LnRF	-6.39962	0.713533	-8.97	0.000***
Population growth (Annual)	-1.210737	0.1665041	-7.27	0.000***

Computation from Stata 13 * p=0.10; ** p=0.05; *** p=0.01

Table 11: Short-run Dynamic Model Results

Lag Dependent LD-LnGDP is the dependent variable				
Variables	Coefficient	Standard Error	T- Statistic	P- Value
Constant	-0.1105073	0.2244751	-0.49	0.623
LD.LnTM	1.004803	2.281878	0.44	0.660
LD.LnRF	0.0555166	0.1404195	0.40	0.693
LD.Lnpden	7.089166	5.030694	1.41	0.159

Computation from Stata 13 * p=0.10; ** p=0.05; *** p=0.01; LD=lag difference;
Ln*=Natural logarithm

rainfall. The lag differences of population density against lag differences in the growth rate of GDP are not statistically significant in The Gambia in the short run.

CONCLUSION

The study used time series analysis in order to determine the short-run and long-run dynamic relationship between economic growth and other variables of interest such as growth rate in rainfall, temperature and population growth in The Gambia. Economic growth is significantly decreased or increased by rainfall and temperature patterns in the country. From the result, population growth annually is highly significant and has a negative impact on economic growth. The growth rate of climate change variables, i.e. temperature and rainfall growth, are all statistically significant and associated with a negative coefficient; thus they both also have a negative impact on economic growth in The Gambia. In the long-run, these variables will all be statistically significant, but surprisingly they have negative impact on the growth rate of the GDP in The Gambia. In the short-run dynamic model, the lag difference of rainfall against its own lag is statistically significant and has a positive impact on economic growth. The consequences of climate change in The Gambia will negatively impact on economic growth resulting in high unemployment, low productivity, a decrease in the standard of living, an increase in government spending, borrowing and deficit culminating in the high poverty rate in The Gambia. The novelty of this study, unlike other Gambia climate change papers, is the utilization of numerous empirical models to account for nuance not captured in the previous studies. We strongly recommend that: 1. Given the long-run negative relationship between economic growth and climate change variables, i.e. rainfall and temperature changes, policymakers should formulate efficient environmental policies that will mitigate the impact of climate change in The Gambia, thereby accelerating economic growth. 2. Owing to the long-run indirect relationship between population growth and GDP in The Gambia, the government should institute policies that will promote family planning to reduce population growth; consequently, this will reduce poverty, given the meagre resources of the country. 3. The Gambia, being prone to environmental and climate shocks, e.g. sea-level rise, erosion, and drought has to create public awareness on climate and environmental education in order to promote reforestation, biodiversity, conservation etc. to sustain economic growth.

AUTHOR CONTRIBUTIONS

C. Belford commenced the process by conceptualizing and formulating the research idea, followed by data collection and cleaning. He was

also extensively involved in reviewing the literature and preparing the manuscript. H. Delin reviewed and edited the final manuscript. E. Ceesay performed the data analysis, results interpretation and discussion. Y. Nasr Ahmed reviewed the analysed data and helped in the data interpretation. L. Sanyang and R. Happy Jonga did the proofreading and literature review.

ACKNOWLEDGMENTS

The authors of this paper wish to express their utmost appreciation to the Institute of Agricultural Economics and Development (IAED) at The Chinese Academy of Agricultural Sciences (CAAS), Beijing, China, for providing all the necessary materials and a conducive academic environment to undertake this research on the economic impact of climate change in The Gambia. The authors wish to also acknowledge the support and forbearance of their respective families.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

ABBREVIATIONS

DF	Dickey-Fuller
ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
ARIMA	Autoregressive Integrated Moving Average
ARMA	Autoregressive Moving Average
BIC	Bayesian Information Criterion
°C	Degree Celsius
CLM	Climate Change Variables
CO2	Carbon dioxide
ECM	Error Correction Model
FAO	Food and Agriculture Organization
GBoS	Gambia Bureau of Statistics
GDP	Gross Domestic Product
GMD	Gambian Dalasis
GRP	Gross Revenue Product
HC	Human Capital
HQIC	Hannan-Quinn Information Criterion
NDP	National Development Plan
POP	Population
SSA	Sub-Saharan Africa
VAM	Vector Autoregressive Model
VECM	Vector Error Correction Model
WB	World Bank
WDI	World Development Indicator

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HOW TO CITE THIS ARTICLE

Belford, C.; Delin, H.; Ceesay, E.; Ahmed, Y.N.; Sanyang, L.; Jonga, R.H.,(2020). The impact of climate change on economic growth based on time series evidence, 1969-2016., Int. J. Hum. Capital Urban Manage., 5(4): 305-318.

DOI: 10.22034/IJHCUM.2020.04.03

url: http://www.ijhcum.net/article_44279.html