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Article

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Climate change, food security and economic growth nexus in the Gambia: Evidence from an econometrics analysis

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ABSTRACT

This paper aims to test econometrically to analysis climate change on food security and other which includes economic growth, population growth and agriculture sector. This paper employed data for the period 1971–2020 from open data bank from (WDI) World development indicator and analyzed this data using Vector Autoregressive Approach (VAR), Granger Causality Approach, Autoregressive Distributed lag mode approach (ARDL) and Error Correction Approach (ECM). Empirical evidence displays, food security growth has strong optimistic correlation with the agriculture sector but negative correlation with rainfall variation. Finally, Population growth has significant negative impact on food security in a short term and insignificant negative impact on food security in the long term. Policy recommendation is that since agriculture is important for food security in the rural Gambia. The government should work on planting more trees for better agriculture and environment, Food security intervention programs, and Poverty reduction programs, provision of more adaptive capacity indicators, Quality and affordable education for all, System changes to bring quality of governance and institution and economic that is working for all and sundry, and consider export economy, the author noted.

Introduction

Economics of the Gambia is mainly dependent on remittance received, agriculture, and tourism (Ceesay et al., 2021). Remittance is the major contribution to GDP 72 percent of the rural households depend on agriculture for survival. In their study, Loum and Fogarassy (2015) revealed that climate change in The Gambia contains the following elements such as the incidence of drought, changes in rainfall, windstorms, and cold spells. FAO (2017) found that food (in)security, malnutrition and poverty have continued unchanged in the Gambia due to lower nutrient in food, floods and drought. Sun and Zhang (2021) found that agriculture and rainfall does not granger causes food security while food security granger cause GDP per capita, According to Sillah (2013) in his study on agriculture and growth confirmed that the productivity of is the key to economic development in the Gambia. In his thesis paper highlight, Patrick (2009) shown that more involvement are needed in North bank region and Western region of the Gambia because of their engagement in livestock and crop production. Bakari et al. (2018) showed in his study that GDP has positive relationship with trade in agriculture. Ceesay et al., (2021) explored the environmental Kuznets

curve hypothesis (EKC) in West Africa found that trade openness and environmental quality has direct relationship. Ali et al. (2019) used ARDL method and established that both short run and long run CO₂ and agriculture production has positive association. A lack of interdisciplinary teaching and cooperation has significantly hindered the advancement in population and environment investigation (Hunter et al., 2014). The IPCC, which submitted its fifth assessment report recently, continued to provide increasing evidences on climate change. There is a growing consensus among climate scientists that global warming is taking place, precipitations are erratic and there is an increase in extreme weather events like floods, droughts and cyclones globally (Trenberth et al., 2014; Stern, 2007; INCCA, 2010). Most prominently, human-caused climate change will influence the quality and quantity of food we produce and our ability to distribute it equitably. Northeast Brazil, Barbieri et al. (2010) claim that climate change will affect agricultural productivity levels, contributing to food insecurity when adaptation mechanisms are not enough to mitigate the economic effects. Furthermore, developing countries will suffer most from the adverse effects of climate change due to a lack of capacity and technology to guard against climate impacts (Gutmann and Field, 2010).

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According to Belford et al. (2020), in Anglophone West African countries, the growth rate of the agriculture sector and temperature are statistically significant (0.008 ** and 0.089*) and have a negative impact (-2.04 and -17.7) on the growth rate of economic. Climate change is serious challenge to agriculture both crop production and livestock management by ways of rainfall fluctuation, drought, heat wave, pest and diseases, water scarcity, food scarcity for both animals and human. Adverse climate changes such as heat waves, droughts, and floods will have the strongest impacts on rural livelihoods that depend heavily on natural resources and the agricultural sector (Boyd and Ibarrran, 2009; Wodon et al., 2014). However, the link between food security, and climate change has been documented (McGregor, 1994; McMichael, 2014) but not empirically verified. This study will add more light on that too to empirical change uses quantitative data to run climate change, economic growth and food security nexus by using econometric techniques. In additional, the problems the research want to explore is that how climate change affect food security and economic growth in the Gambia taking account growth rate of agriculture sector. Section 1: introduction, Section 2: Hypothesis testing, Section 3: Theoretical framework, Section 4: Data Collection, Data measurement, and Data Presentation, Section 5: Material and method, Section 6: Results, Section 7: Interpretation of estimation Parameters, Section 8: Conclusion and Policy Recommendation.

The research question is: How might climate change affect food security and economic growth in the Gambia?

The Specify objective of the study is: To determine the impact of climate change on food security and economic growth in the Gambia.

Hypothesis testing

H₀ : The mean of Climate change in the Gambia does not correlated with food security and economic growth.

H₁ : The mean of Climate change in the Gambia is correlated with food security and economic growth.

Theoretical framework

The paper adopts the theoretical concept of production function by including climate variables into it as used by (Nicholas et al., 2011; lee and lee 2012; Ceesay 2020; Belford et al., 2020), which forms the theoretical basis for the study. Since growth accounting equation offers guidance for the decomposition of climate change, agriculture value added, economic growth, and their impact on food security as derived below:

$$FSFP_{it} = F(AAR_{it}, AFFVAC_{it}, GDPPC_{it}, L_{it}, K_{it}) \tag{1}$$

Where:

- Y_{it} = FSFP_{it}: Food security, at time t and observation i
- AAR_{it}: is average annual rainfall (Proxy for climate change at time t and individual i).
- AFFVAC_{it}: Agriculture valued added
- L_{it}: Total labor force.
- K_{it}: Gross capital formation.
- GDPPC_{it}: GDP Per capita as a proxy for economic growth.

Food security is a function of the real capital stock (proxy variable Gross capital formation), labor(Labor force proxy), Climate change (Proxy average annual rainfall), economic growth, and Agriculture valued added. From equation 1, we get the following as adopted from (Dell et al., 2008), (Ceesay (2020) and (Bond et al., 2010) and Belford et al. (2020).

$$Y_{it} = FSFP = Ab^{\alpha T_{it}} K_{it}^{\rho} L_{it}^{1-\rho-\sigma-\theta-\pi} AAR_{it}^{\sigma} AFFVAC_{it}^{\theta} GDPPC_{it}^{\pi} e^{\epsilon} \tag{2}$$

Such that: $\rho + \alpha + \sigma + \theta + \pi = 1$

$$\frac{\Delta A_{it}}{A_{it}} = g_i + \beta T_{it} \tag{3}$$

Where Y is Food security, L is Labour(proxy labour force), A is technology and can also be referred to as labour productivity or Total factor productivity, K is gross capital formation, T is the impact of climate change (average annual rainfall proxy), g is the growth rate of capital, t is time period and e is exponential and ε is a constant and it is also the error term in the model. Equation 2 captures the direct effect of climate change, economic growth, and agriculture value added on food security e.g. effects on labor productivity and equation 3 captures the indirect (dynamic) effect of climate change e.g. the effect of climate change on other variables that indirectly impact food security.

Presenting natural logarithm into equation 2 and deviating with respect to time period, we derived equation 4 below:

$$g_{it} = g_i + (\alpha + \beta)T_{it} - \alpha T_{it-1} \tag{4}$$

Where g_{it} is the growth rate of output, direct effects of climate change on food security are accounted for by α such as change in rainfall and indirect effects are accounted for by β such as impact of climate change, flooding or drought on other variables that indirectly influence food security.

The study will observe both the direct and indirect effects of climate change, agriculture value added, and economic growth on food security of The Gambia for the periods under investigation. This variations will provide an insightful knowledge on which food security indicators is mostly affected under the following conditions, climatic, agriculture, economic growth that affect the food security in The Gambia.

Data collection, data measurement, and data presentation

World Development Indicators-WDI is the primary World Bank collection of development indicators, compiled from officially recognized international sources from each country, continent, and global. It gives the most current and accurate global development data and includes national, regional, and global estimates. Therefore, the World Bank used to collect data and measure it based on aggregation rules. According to World Bank, aggregate measures are based on regional and income classification of economies. The rules are intended to yield estimates for a consistent set of economies from one period to the next; For Example, it collects, compiles, and calculates the growth rate based on an annual average and is represented as percentages. It can use either exponential or least square methods to calculate the economy's growth rate. This aggregation is applied to educational indicators, gender indicators, agriculture indicators, health, poverty, climate change, environment, energy, governance, consumption, GDP, investment, exchange rate, and debt. Further, a brief description of the data, the name of the variables, data sources, and comments given in this article are presented in Table 4 below: As from the World Bank, the description of each variable is as follows; Agriculture corresponds to forestry, hunting, and fishing, Cropping and livestock Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. GDP per capita (GDPPC) is gross domestic product divided by population. GDP is the total sum of gross value added by all resident producers in the economy, added to any product taxes, and minus any subsidies not included in the value of the products. The food production index-food security (proxy food availability) covers food crops considered edible and containing nutrients. The annual population growth rate for year t is the exponential growth rate of the mid-year population from year t-1 to t, i.e., previous to current, expressed as a percentage. An adequately exposed thermometer indicates the average temperature of the air during a given period, usually a day, a month, or a year. An average annual rainfall means the average amount of precipitation/rainfall for a station over a year based on measured by the nearest National Weather Service station/meteorological station for the preceding three decades using the aggregation method.

Table 1

Data.

Name of Variable	Source	Comment
GDP per capital	WDI	GDP per capita
Agriculture	WDI	Agriculture value added of \$
Food Security	WDI	Food production
Rainfall	WDI	Average annual rainfall
Population Growth Annually (%)	WDI	Population growth rate
GDP current	WDI	GDP current \$

Own Compilation extracted from WDI data.

Table 2

Descriptive Statistic.

Variable	Obs.	Mean	Std	Min	Max
LNFSFP	49	4.266967	0.2081572	3.821442	4.799091
LNGDPPc	49	6.098171	0.5633579	4.758396	6.829266
LnAAR	48	4.365117	0.1619503	3.963814	4.653288
LNAFFVAc	49	18.64221	0.9270481	16.64361	20.1128
LNGDPC	48	19.73353	0.9853207	17.62592	21.0893
LNPG	48	1.186681	0.1405012	1.043032	1.60516

Own evaluation.

Material and method

Empirically the Vector Autoregressive (VAR) model

VAR-Vector auto-regression is a stochastic procedure in time series to find the linear interdependencies among variables. The error it is presumed to be white noise procedures, which may be contemporaneously connected and are uncorrelated with both past or future disturbances. According to sim 1980 VAR model variables in macro econometric as a way of multivariate simultaneous equations.

In a VAR model, the dependent variable is a function of its own lagged and the lagged values of other variables. VAR must be stated in the levels form. In the other equations, growth of food security or climate change variables as endogenous and they depend on own lags as exogenous and plus other control variables as exogenous too. Finally, the study will use others control variables as endogenous to depend on its lags as exogenous and the lags of additional exogenous variables such as food security, and climate change variables.

The equation for empirical VAR can be represented below:

LNFSFP Food Production from WDI as a proxy of food security.

$$LNFSFP = \alpha + \sum_{i=1}^p \gamma_i LNFSFP_{t-i} + \sum_{j=1}^p \beta_j lnAFFVAC_{t-j} + \sum_{k=1}^p \theta_k lnGDPPc_{t-k} + \sum_{l=1}^p \delta_l lnAAR_{t-l} + \epsilon_{1t} \tag{1}$$

Agriculture value added (current US\$) as a proxy of agriculture sector.

$$lnAFFVAC_t = \varphi + \sum_{i=1}^p \gamma_i lnGDPPc_{t-i} + \sum_{j=1}^p \beta_j AFFVAC_{t-j} + \sum_{k=1}^p \theta_k lnFSFP_{t-k} + \sum_{l=1}^p \delta_l lnAAR_{t-l} + \epsilon_{2t} \tag{2}$$

Average Annual rainfall (AAR) as a proxy of climate change.

$$lnAAR_t = \pi + \sum_{i=1}^p \gamma_i lnFSFP_{t-i} + \sum_{j=1}^p \beta_j lnGDPPc_{t-j} + \sum_{l=1}^p \delta_l lnAAR_{t-l} + \sum_{m=1}^p \delta_i lnAFFVAC_{t-m} + \epsilon_{3t} \tag{3}$$

GDP Per capital.

$$lnGDPPc_t = \sigma + \sum_{i=1}^p \gamma_i lnFSFP_{t-i} + \sum_{j=1}^p \beta_j lnAFFVAC_{t-j} + \sum_{k=1}^p \theta_k lnAAT_{t-k} + \sum_{l=1}^p \delta_l lnAAR_{t-l} + \sum_{m=1}^p \rho_l lnGDPPc_{t-m} + \epsilon_{4t} \tag{4}$$

Impulse response function

The function returns the dynamic reply to a one-standard-deviation tremor to a variable in a VAR(p) model. To evaluation the IRF of a dynamic linear model categorized by structural, auto-regression, IRFs suggestion the impacts of a novelty tremor to one variable on the reply of all variables in the method.

The IRF equation is formulated below;

$$y_{t+h} = \gamma_h + \vartheta_h shock_{CO2yt} + \delta_h(L)Z_{t-1} + quadratic\ trend + \epsilon_{t+h} \tag{5}$$

where y is the variable of interest such as economic growth, food security and other control variables in the model, shock is the identified shock if either food security are shock or other control variables if and only if we take account the interest variables as economic growth or food security vice versa. Z is a vector of control variables, and $\delta_h(L)$ a polynomial in the lag operator. All regressions for IRFs' contain two lags of the shock-to wash up any serial correlation that can happened, transformed food security, transformed GDP per capital, and the other control variables. The ϑ_h as a coefficient delivers the reply y at time $t+h$ to the shock on time t if we nominated food security as the interest variables and otherwise will modification.

ARDL bounds testing procedure for Co-integration

Practice ARDL bounds testing for co-integration is to evaluate climate change and food security nexus. The ARDL bound testing methods as established by Pesaran et al.(2001), Nicholas et al. (2011), lee and lee (2012), Ceesay (2020), Belford et al. (2020), Dell et al. (2008), Pesaran (2007), Menegaki (2019), Alkire (2002) and Thursby et al. (1977), which is improbable the other approaches, we can factor the impact of lags on the variables for longer period. The ARDL bound testing technique for co-integration is a healthier approaches and it gives unbiased outcomes (Haug 2002; Alimi, 2014). The ARDL equations can be stated as:

ARDL model

$$lnFSFP = \alpha_0 + \sum_{i=1}^p \alpha_i lnFSFP_{t-i} + \sum_{i=0}^q \beta_{1i} lnGDPPc_{t-i} + \sum_{i=0}^p \beta_{2i} lnAFFVAC_{t-i} + \sum_{i=0}^p \beta_{3i} lnAAR_{t-i} + \sum_{i=0}^p \beta_{4i} lnGDPC_{t-i} + \sum_{i=0}^p \beta_{5i} lnPG_{t-i} + \lambda_1 lnFSFP_{t-1} + \lambda_2 lnGDPPc_{t-1} + \lambda_3 lnAFFVAC_{t-1} + \lambda_4 lnGDPC_{t-1} + \lambda_5 lnPG_{t-1} + \lambda_6 lnAAR_{t-1} + \epsilon \tag{6}$$

$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ are short run coefficients and $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \lambda_6$ are long run coefficients. Pesaran and Shin (1999) and Pesaran, et al 2001 was used to check for co-integration.

ECM

VECM (vector error correlation model) model. Illustration on effort of

Table 3
Correlation.

Variable	LNFSFP	LNAFFVAc	LNGDPPc	LNPG	LNGDPC
LNAFFVAc	0.3591	–			
LNGDPPc	0.2489	0.9338	–		
LnAAR	0.0793	0.3089	0.2481	–0.0743	0.2617
LNPG	–0.4100	–0.2086	–0.0776	–	
LNGDPC	0.3738	0.9200	0.8942	–0.1885	–

Own Compilation.

Granger (1969) and Sims (1972), the causal connection can be tested inside in order to frame the (ECM)Error Correction Model. We apply the Granger causality in ECM as in (Guliky and Salemi, 1982; Gewekeetal, 1983). The Granger causality test founded of VECM is thus strong-minded by the next ARDL models:

$$\begin{aligned}
 lnFSFP = & \alpha_0 + \sum_{i=1}^p \alpha_i lnFSFP_{t-1} + \sum_{i=0}^q \beta_{1i} lnGDPPc_{t-1} + \sum_{i=0}^p \beta_{2i} lnAFFVAc_{t-1} + \sum_{i=0}^p \beta_{3i} lnAAR_{t-1} + \sum_{i=0}^p \beta_{4i} lnGDPC_{t-1} + \sum_{i=0}^p \beta_{5i} LnPG_{t-1} + \lambda_1 lnFSFP_{t-1} \\
 & + \lambda_2 lnGDPPc_{t-1} + \lambda_3 lnAFFVAc_{t-1} + \lambda_4 lnGDPC_{t-1} + \lambda_5 lnPG_{t-1} + \lambda_6 lnAAR_{t-1} + ECM_{t-1} + \epsilon
 \end{aligned} \tag{7}$$

ECMt-1 signifies lagged value after running the long run model and generate the residual (see Table 1).

Results

Data used in the study

The data for this paper is obtainable from World Development Indicators (WDI). Table 2 displays descriptive statistics. Change in agriculture sector has the uppermost average and it is also related with the top standard deviation. Food security has an average value of 4.27 approximately and standard deviation of 0.208. Change in Gross

Table 4
Unit root test.

Variable Names	ADF		PP		KPSS	
	Level.ADF	1st Diff	Level.PP	1st Diff	Level.KPSS	1st Diff
LNGDPPc	–2.419	–4.62***	–2.281	–6.70***	1.0514***	0.14529
LNAFFVAc	–1.848	–5.69***	–1.871	–6.92***	1.2448***	0.17019
LNGDPC	–1.718	–4.07***	–1.818	–6.40***	1.1328***	0.16581
LNFSFP	–1.548	–6.12***	–2.387	–9.95***	0.58296**	0.13772
LNPG	–5.060***	–7.10***	–1.631	–2.348	0.22454	0.11485
LnAAR	–4.407***	–7.31***	6.162***	–10.79***	0.37114*	0.10114

Note: *, ** and *** are statistically significant at 10 percent, five percent and one percent, respectively.

Source: Authors’ calculation using Stata 16 for window.

Table 5
Co-integration test.

Hypothesized No. of CE(s)	Trace Statistic	Eigenvalue	Max-Eigenvalue Statistic	Critical Values (0.05) Trace Max Eigen	Prob. Trace Max-Eig
None	40.9210***	0.3992	22.4206***	47.8561 27.5843	0.1912 0.1996
At most 1	18.5004***	0.1951	9.5475***	29.7971 21.1316	0.5293 0.7860
At most 2	8.9529	0.1304	6.1485	15.4947 14.2646	0.3697 0.5942
At most 3	2.8044**	0.0617	2.8044**	3.8415* 3.8415**	0.0940 0.0940

Source: Compiled by author’s from cointegration results using Eview 12 SV(x64).

Max-Eigenvalue test shows no cointegration at the 0.05 level.

Trace test specifies no cointegration at the 5% level.

Note: **,*** signify significance at 5% and 1% level of significance.

Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 analytic asymptotic S.E.s

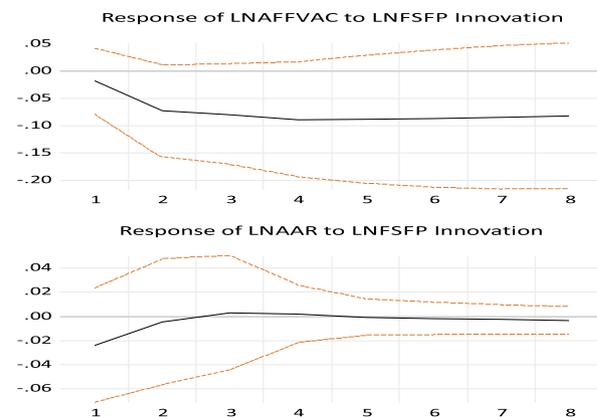


Fig. 1. Graphs impulse response function Using Eviews 12 SV(x64).Year = Period.

domestic product has a mean (19.73) and accompanying with the maximum standard deviation (0.99) and minimum (17.63) and maximum(21.09).

The correlation is defined to control association among two variables. Relationship between food security growth and population growth rate is negative. Therefore, growth of population escalates by 1 unit then the rate of growth of food security decline by 41 %. The growth of agriculture value added is also destructively influence on the population growth. In addition, the rate growing of climate change has a bad connection with the growing of population annually (Table 3). Therefore, Climate change affect agriculture and that in turn causes food shortages and therefore the relationship between food security and

Table 6
FEVD.

Variance Decomposition of LNFSFP					
Time Period	S.E	LNFSFP (%)	LNGDPPC (%)	LNAFFVAC (%)	LNAAR (%)
1	(0.1595)	100.0000	0.000000	0.000000	0.000000
2	(0.1733)	98.05885	0.751698	1.043083	0.146368
3	(0.1812)	97.79479	1.114485	0.954342	0.136386
4	(0.1843)	97.55254	1.286072	1.004826	0.156564
5	(0.1858)	97.14988	1.422628	1.255780	0.171716
6	(0.1868)	96.60350	1.543684	1.679804	0.173008
7	(0.1876)	95.96125	1.649860	2.216058	0.172828
8	(0.1883)	95.28834	1.750618	2.788213	0.172829
9	(0.1889)	94.62237	1.850004	3.354912	0.172713
10	(0.1896)	93.98754	1.947502	3.892347	0.172607

Own Evaluation Using Eviews 12.

Table 7
Granger Causality test outcomes.

	Fail to reject: $\gamma_{yx_1} = \gamma_{yx_2} = \dots \gamma_{yx_i} = 0$	Reject: $\gamma_{yx_1} = \gamma_{yx_2} = \dots \gamma_{yx_i} = 0$
Fail to reject: $\gamma_{yx_1} = \dots$ $\gamma_{yx_2} = \dots$ $\gamma_{yx_i} = 0$	$y \nRightarrow x$ (no granger causality)	$y \Leftrightarrow x$ (bidirectional relationship)
Reject: $\gamma_{yx_1} = \dots$ $\gamma_{yx_2} = \dots$ $\gamma_{yx_i} = 0$	$x \nRightarrow y$ $y \Rightarrow x$ (y cause x and x does not cause x = unidirectional relationship)	$x \nRightarrow x$ $x \Rightarrow y$ (x causes y and y does not cause x = unidirectional relationship)

Own Evaluation.

climate change is slightly positive and near to be zero.

Unit root tests

Table. Presents the results of Augmented Dickey-Fuller (ADF) unit root test, Phillips-Perron (PP) unit root test and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root test for all variables in levels and first differences using the time series annual data from 1971 to 2020. According to both the ADF and PP tests, the LNGDPPc, LNAFFVAc, LNGDPC and LNFSFP variables were not stationary in their level forms but they became stationary at their first differences at the 1 % level of alpha. Further, the ADF test show that LNPG and LNAAR are stationary both in the level and first differences.

Growth rate of population is not stationary at both the level and first differences for the PP and KPSS tests. For the KPSS test, only LNAAR is stationary at 10 % level of statistical significance at the level form. None of the variables were stationary at the first differences for the KPSS test. Hence, the variables were integrated of the different order in the level and first differences and none of the variables for the Gambia is integrated at second order, I(2). Therefore, the appropriate model is ADRL (see Table 5).

i. Pre-estimation tests.

Stability test of assessed VAR models: To checks whether the

Table 8
Granger causality outcomes.

Equation	Excluded	Direction	P-value	Equation	Excluded	Direction	P-value
LNFSFP	LNGDPPc	INDI	0.905	LNGDPPc	LNFSFP	DI	0.028**
LNFSFP	LNAFFVAc	INDI	0.517	LNGDPPc	LNAFFVAc	INDI	0.143
LNFSFP	LnAAR	INDI	0.574	LNGDPPc	LnAAR	INDI	0.559
LNFSFP	Overall	INDI	0.350	LNGDPPc	Overall	INDI	0.103

Source: Authors' computation, 2020. N.B. * p = 0.10, ** p = 0.05, *** p = 0.01 note DI is direct/granger, INDI is indirect/not granger.

stability circumstances required to calculate IRFs and FEVDs. To test the stability we use Varstable and Varstable, graph commands in Stata. The results revealed that all the eigenvalue of the four variables selected lie inside the unit circle, because their modulus less than one and VAR stability conditions are satisfied or meet as shown in Fig. 1.

Normality test.

For Jarque- Bera test for normality tests of errors have the critical probability is significant. The LNGDPPc, LNAFFVAc, LNGDPC, LNPG, LNAAR and LNFSFP follow normal and lognormal rules.

Breusch-Godfrey LM test for correlation of errors.

The Breusch-Godfrey test a Lagrange multiplier (LM) test. The theory test is that H0: the error are uncorrelated and H1: the error terms are associated. The disturbance terms are connected since the p value is greater than BG.

Heteroskedasticity tests: White test case.

The theory is H0: disturbance terms are homoskedasticity and H1: if disturbance terms are heteroskedasticity.

Option 1: No cross terms.

The White statistic is 3.2457 and the p value is 0.7774. The model for the error terms are homoscedasticity at 0.05.

Option 2: Cross terms.

The White statistic is 29.222 and the p-value is 0.3502. The errs are unrestricted at the 0.05.

Simulation of the model.

The curves of real and fitted are around the mean and the model is stationary. The simulation is good as designated in the graph above. The data has probable a high projecting power since it replicates precisely the previous (see details in Fig. 8).

Co-integration test

The amount of co-integrating associations for the four variables, based on trace statistics and eigenvalue statistics at 5 % level of significance is in Table 6. No co-integration among the variable is rejected at 5 percent (see Table 7).

VAR outcomes and discussion

The Vector autoregressive (VAR) outcomes revealed. The growth of agriculture takes negative insignificant influence on food security at lag 1 and positive insignificant impact on food security at lag 2. This outcome is a priori expectations because agriculture does not cause food security due to minor level of adaptive technology attached to agriculture development. In similar vein, food security has major adverse influence on agriculture. Due to climate change extreme event problems, growing of mean annual rainfall as a proxy variable for climate change has negative significant impact on food security and agriculture at lag 1. At lag 1, GDP per capita has insignificant negative impact on the growing of agriculture. Outcomes are consistent with the following study (Kamitewoko (2021), Kinda (2021), and Ceesay et al., (2021)) in which they found negative association amid food security and these variables.

Overall results, the theoretical insinuations of these variables can extra be assessed from the forecast error variance decomposition(FEVD). In this article, we are concerned with the status of the progress of climate change, development of agriculture, and growing of GDP per capita

Table 9
Granger causality test results.

Equation	Excluded	Direction	P-value	Equation	Excluded	Direction	P-value
LNAFFVAc	LNFSFP	DI	0.058**	LnAAR	LNFSFP	INDI	0.858
LNAFFVAc	LNGDPPc	INDI	0.318	LnAAR	LNGDPPc	INDI	0.291
LNAFFVAc	LnAAR	INDI	0.924	LnAAR	LNAFFVAc	DI	0.077*
LNAFFVAc	Overall	INDI	0.276	LnAAR	Overall	DI	0.088*

Source: Authors' computation, 2020. N.B. * p = 0.10, ** p = 0.05, *** p = 0.01. nte DI is direct Granger, INDI is indirect/not Granger.

Table 10
Results of F- Bounds test for Cointegration.

Dependent Variable Models	lags	F- Statistics	Co-integration	Further
LNFSFP	ARDL (1,2,3,3,3,1)	$F_{LNFSFP} = 5.673$	Yes	Estimate ECM (long-run model)
		$t_{LNFSFP} = -5.428$		
LNAFFVAc	ARDL (1,0,0,1,0,1)	$F_{LNAFFVAc} = 1.865$	No	Estimate ARDL Model (short-run model)
		$t_{LNAFFVAc} = -2.327$		
LnAAR	ARDL (1,0,1,0,2,2)	$F_{LnAAR} = 9.925$	Yes	Estimate ECM
		$t_{LnAAR} = -7.172$		
LNGDPPc	ARDL (1,0,1,0,0,1)	$F_{LNGDPPc} = 3.233$	Inconclusive	???????
		$t_{LNGDPPc} = -3.207$		
LNGDPC	ARDL (2,4,3,0,4,1)	$F_{LNGDPC} = 4.801$	Yes	Estimate ECM
		$t_{LNGDPC} = -1.173$		
LNPG	ARDL (3,0,0,3,0,3)	$F_{LNPG} = 5.299$	Yes	Estimate ECM
		$t_{LNPG} = 0.406$		

Source: Author's calculation using Stata 16 for Windows.
*, **, *** denote significant at 10%, 5%, and 1% level of significance respectively.

shocks on growth of food security. The shocks in food security extended within 100 percent in the first year lessening to about 98 percent in the period 2, deteriorating further to 97 percent in year 3,4 and 5, 96 percent in period 6 and 95 percent in year 7 and 8, 94 percent and 93 percent in period 9 and 10 respectively. So we can see that in the shocks in food security in most of the two years connectives are similar in most cases due to similar variations of climate change and others inputs affect smallholder agriculture farmers in the Gambia especially rural areas, where mainstream of them are subsistence farmers. See details in Table 8.

From the Fig. 3 Above, the Impulse response functions delivered by VAR models are used to distinguish where the influence of alteration in one variable can be create over all the other variables. Then, a response of agriculture sector to food security, a one standard deviation shock (innovation) to growth of food security initially has clear slightly optimistic impact on agriculture sector in period 1 and negative impact on period 2 correspondingly. From year 2 the response, the response gradually declines up to period 5.6 years i.e. 5 year and 6 months, when

Table 11
Short-run Coefficients and (ECM) error correction coefficient. Dept. Variable is.. $\Delta \ln FSP_t$

Variables	coeff.	std.error	t-Statistic	prob.
C	0.0335	(0.0261)	1.2468	0.2199
$\Delta \ln LNFSFP(-1)$	-0.3542***	(0.1450)	-2.4427	0.0192
$\Delta \ln LNAFFVAc(-1)$	-0.1122	(0.2056)	-0.5457	0.5884
$\Delta \ln LnAAR(-1)$	0.0834	(0.1140)	0.7318	0.4689
$\Delta \ln LNGDPPc(-1)$	0.2782	(0.2249)	1.2369	0.2235
$\Delta \ln LNGDPC(-1)$	-0.3090**	(0.1490)	-2.0733	0.0448
$\Delta \ln LNPG(-1)$	-1.0526**	(0.5161)	-2.0395	0.0482
ECM(-1)	-0.7201**	(0.2811)	-2.5616	0.0145

Estimated Long run Coefficients. Dependent variable is $\ln FSP_t$				
Variables	coeff.	std.error	t-ratios	p-value
C	1.9546	(0.10826)	1.8055	0.0785*
LNFSFP(-1)	0.4491	(0.1428)	3.3556	0.0017***
LNAFFVAc(-1)	0.0704	(0.014)	0.7708	0.4454
LnAAR(-1)	0.0929	(0.1522)	0.6104	0.5451
LNGDPPc(-1)	0.0853	(0.1339)	0.6365	0.5281
LNGDPC(-1)	-0.0799	(0.0644)	-1.2405	0.2220
LNPG(-1)	-0.3276	(0.1840)	-1.7805	0.0826*

*** and ** and * denotes significant at 1% and 5% and 10% level of significances respectively.

Source: Authors' calculation using Stata 16.

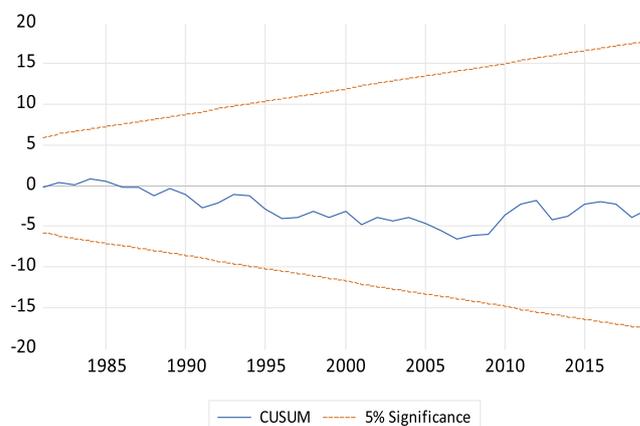


Fig. 2. Cusum test when short run food security is the dependent variable.

it hit steady state value at year. Beyond the 6 period, development of agriculture sector increases above the maximum state value and remains in the undesirable region. Shocks to food security will have a slightly optimistic effect on agriculture sector in the short term and substantially adverse effect in the long term. Food security shocks will also lead to poor agriculture in the long term. The reply of climate change shock to food security, one standard deviation shock (innovation) to food security current has harmful influence on climate change in period 1 and period 2. From year 3 to period 4 the climate change answer to food security was positive and it remains negative from year 5 to period 8. Shocks to food security in the Gambia will have a positive influence on climate change in one year (medium run) and in all other periods the shocks to food security will have adverse effect on climate change in the long run and even in the short run. As food security is shocks, the climate

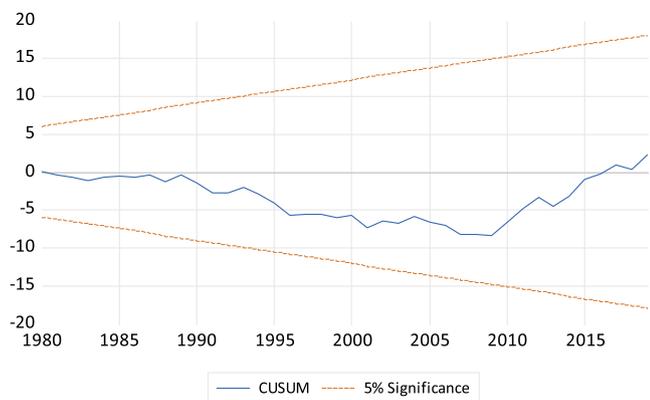


Fig. 3. Cusum test when long run food security as dependent variable.

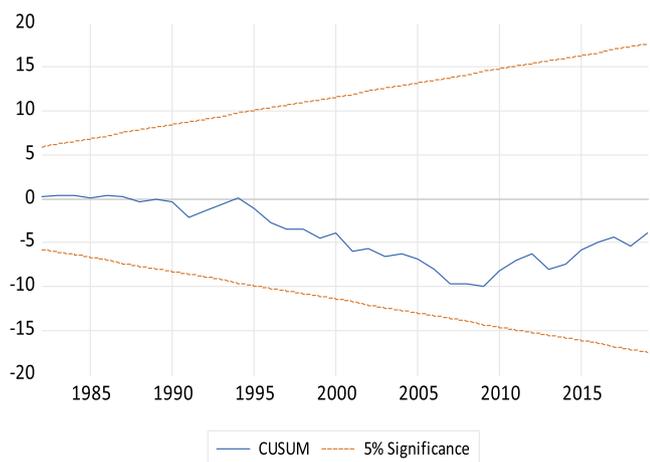


Fig. 4. Cusum after ECM when the dependent variable is food security.

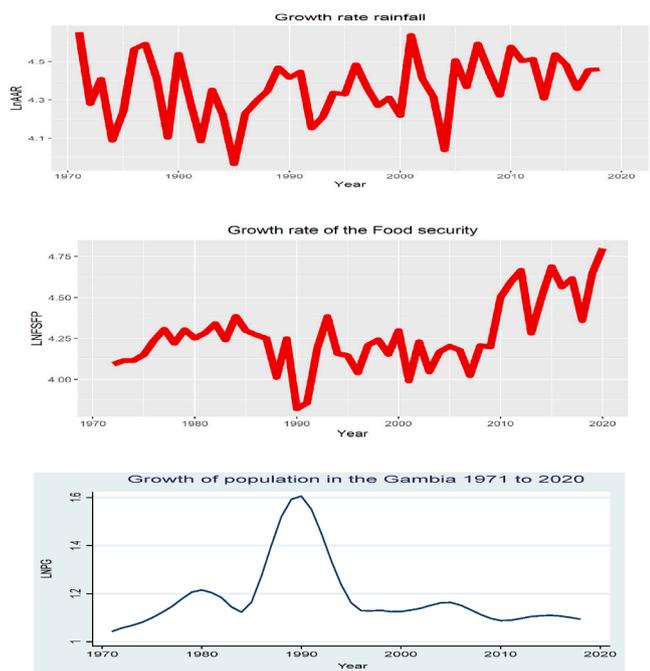


Fig. 5. Growth of rainfall, Growth of Food Security and Growth of Population annual.

change crisis will be more severity in the short and long run (see Table 9).

Granger causality

The main aim of relating the VAR Granger Causality test is to confirm whether there is a causal relationship between the diverse variables.

The outcomes in Table 10 illustration a astonishing image as the progress of food security causes expansion of GDP per capita but per capita GDP does not causes the food security growth -unidirectional relationship (see Table 11).

Table 10 above, food production index does impact agriculture positively. The result is indirect. Agriculture Growing does not lead to development of food security proxy food production index-unidirectional relationship. Planting more trees for more rainfall to come and that in turn rises the productivity of agriculture. Therefore, Progress of agriculture causes growing of rainfall and growing of agriculture significantly causes progress of the rainfall and reciprocal for growth of rainfall on the development of agriculture-unidirectional relationship. The shifting rainfall affect agriculture and food security = bidirectional relationship. The changing of rainfall is irrelevant effect on the development of agriculture and food security. It is confirmed that (Ceesay et al., (2021)) and (Sun and Zhang, 2021). Likewise, agriculture does not cause GDP and rainfall does not cause per capita gdp as well, the study noted. This is also confirmed in the following study (He & Lee, 2016; Singh & Borrok, 2019).

ARDL estimation

Subsequently meeting the situation of strict first-difference stationary in the ADF,PP and KPSS tests above for the dependent variable (LNFSFP), we control the optimum lag for the anticipated model. The minimum lag length is -12.12* and under (AIC). Therefore, the best lag is three using AIC. Using the optimal lag designated for co-integration using Pesaran, Shin, and Smith (PSS) bounds below. Hence, the unit root test result in above demonstration a mixture of I(1) and I(0).

F-Bound test Approach for Co-integration for food security in the Gambia

The outcomes accessible stated in Table 16 specify significant cointegration between food security(LNFSFP), Agriculture sector(LNAFF-VAc), (LnAAR) climate change(average rainfall proxy), (LNGDPC) economic growth(GDP Current as a proxy) and population growth (LNPG). In model 1, the F-bound statistics value of 5.673 is larger than the critical value of upper bounds, I(1) on 10 %, 5 %, 2.5 % and 1 % levels of significance, which indicated that cointegration between food security as the dependent variable, agriculture sector, economic growth, climate change and population growth. Henceforth, cointegration exist among the variables in the model, the appropriate model is to evaluation the long term coefficient of the ARDL, which contain the error correction model(ECM).It is logic to understand the long term stability contain the short term equation in the ARDL model. In this case we will approximation both the short term and long term.

In model 2, when agriculture sector is the dependent no cointegration exist among the variables, because the intended F statistic 1.865 exists below the (CV)critical values of lower bounds,I(0) at 1 %,2.5 %,5% and 10 % levels of significance correspondingly. In this case, the suitable model to develop after cointegration is to estimate the short term part of the equation.

Specification of ARDL Short-run, ARDL Long-run and ARDL Error correction Equations.

- 1) Specifications of Short-run ARDL models.
- Dependent Variable: Food Security.

$$\Delta \ln FSP_t = \varphi + \sum_{j=1}^p \beta_j \Delta AFFVAC_{t-j} + \sum_{k=1}^p \theta_k \Delta \ln FSP_{t-k} + \sum_{l=1}^p \delta_l \Delta \ln AAR_{t-l} + \sum_{i=1}^p \gamma_i \Delta \ln GDPP_{t-i} + \sum_{i=1}^p \gamma_i \Delta \ln GDPC_{t-i} + \sum_{i=1}^p \gamma_i \Delta \ln PG_{t-i} + \epsilon_{2t} \tag{8}$$

d(lnfsfp) c d(lnfsfp(-1)) d(lnaffvac(-1)) d(lnaar(-1))d(lngdppc(-1)) d(lngdpc(-1)) d(lnpg(-1)).

In Figs. 2, 3 and 4 after running short-run ARDL model, after running long term ARDL model and after running error correlation model. The constancy of the long term estimates was control by using the cumulative sum test method.CUSUM determine stability and the coefficients are stable once the dependent variable is food security. For example, the test controls the stability of the variance of the model. The tests show that the estimate and the variance were steady as the errs reduction inside 5 % critical limits. The null hypothesis expectations are disallowed in the examinations.

2) Specifications of Long-run ARDL model:

$$\ln FSP_t = \alpha_0 + \lambda_1 \ln FSP_{t-1} + \lambda_2 \Delta AFFVAC_{t-1} + \lambda_3 \ln AAR_{t-1} + \lambda_4 \Delta \ln GDPP_{t-1} + \lambda_5 \Delta \ln GDPC_{t-1} + \lambda_6 \Delta \ln PG_{t-1} + \epsilon \tag{9}$$

(lnFSP)c(lnFSPc(-1))(lnAFFVAc(-1))(lnAAR(-1))(lnGDPPc(-1))(lnGDPC(-1))(lnPG(-1))

lnfsfp c lnfsfp(-1) lnaffvac(-1) lnaar(-1) lngdppc(-1) lngdpc(-1) lnpg(-1).

3) ARDL Error correction model Specifications:

$$\Delta \ln FSP_t = \alpha_0 + \sum_{i=1}^p \alpha_i \Delta \ln FSP_{t-i} + \sum_{i=0}^q \beta_{1i} \Delta AFFVAC_{t-i} + \sum_{i=0}^p \beta_{2i} \ln AAR_{t-i} + \sum_{i=0}^p \beta_{3i} \Delta \ln GDPP_{t-i} + \sum_{i=0}^p \beta_{4i} \Delta \ln GDPC_{t-i} + \sum_{i=0}^p \beta_{5i} \Delta \ln PG_{t-i} + \tau ECM_{t-1} + \epsilon \tag{10}$$

d(lnFSP)cd (lnFSPc(-1))d(lnAFFVAc(-1))d(lnAAR(-1))d(lnGDPPc(-1))

d(lnGDPC(-1))d(lnPG(-1)) ecm(-1).

d(lnfsfp) c d(lnfsfp(-1)) d(lnaffvac(-1)) d(lnaar(-1)) d(lngdppc(-1)) d(lngdpc(-1)) d(lnpg(-1)) ecm(-1).

Interpretation of estimation parameters

Table 17 shows the short and long run coefficient evaluations of ARDL when the dependent variable is the logarithm of food security. It displays that, a alteration in the growing of food security on it owns lag is significant and negative in the short term. The degree of development of agriculture sector is important harmful impact on the growth rate of food security. A 100 % increase in growth of agriculture clues to lessening of growth of food security by 0.1122 %.This mean that family farms agriculture does not sufficiently solve the food supply in Gambian’s household and therefore the government should shift farmers from traditional agriculture to modern ways of farming such as comes with new technology such as irrigation, adaptation, mitigation and resilience to fight climate change and as well as to solve the glitches associated with food security. In order to have that the subsistence farmers should be provided with the following like credit or loans, frequently agriculture extension workers to visit their farmlands, provision of fertilizer, pesticide, insecticide, tractors, and any modern equipment that will make work easier and quicker and can translate to high yields and huge income. Which of course will enhance productivity for both the farmers and the government thereby reduces food import and increases food export. This is confirmed by Patrick (2009). The GDP per capita has adverse result on food security using ARDL short run approaches. This is long-established by Ali, S et al., 2019. The study

further revealed that average rainfall as a proxy variable for climate change is insignificant positive correlation with the growth rate of food security at lag 1 in the short-run. The climate change extreme it insignificant may be attributed to shifting patterns of rainfall in the Gambia in the month of August to October and this cost farmers to loss potential yields from their production. At the time of distribution climate change strategy reason transportation and marketing distressed and this led to insufficient food security due to lesser food export and high food import and which lead economic to reduce. Economic growth as a proxy for GDP is destructive significant impact of the growth of food security in the short term.10 % increases in economic growth deteriorations the growth of food security by approximately 0.03 %. This is attributed to reduced budget assigned to agriculture, which translate to lower food production and productivity. The general economy is dampened down to negative. The result also revealed that population growth is important undesirable influence on food security the short term. A percentage rise population annually reduction food security by 0.0105 %.The government of the Gambia should be careful about food security problems because it means that more population, numerous mouth to feed and associated with less food supply, the study noted. Therefore, the government of the Gambia should allocate more budget to agriculture thereby to be able to feed the growing population. On the other hand to deal with population increment, the government should look at fertility rate and maternal mortality rate. The government should also provide frontier knowledge on pathways and linkages on how agricultural, food and nutrition policies influence population outcomes such as malnutrition, dietetic diversity, overweight, stunting, underweight and wasting. For instance, in the long-run food security is substantial positive effect on it owns lag. Correspondingly in the short-run, population growth is vital negative effect on food security in the long run. A percentage growth in population there is a drop in food security by 0.033 %. This is enormous reduction in food security. Unless we intervene on the population, the impact on food security will likely escalates. The following are vital such as agriculture, fertility rate and maternal mortality rate. Climate change is one of the threats to humanity as at now and in the future. The fluctuation of rainfall, the fluctuation of temperature, floods, droughts, degradation of land, windstorm, rainstorm, salt intrusion, artificial pollution like the one from cars, nonrenewable energy etc disturb most of the peoples and our environment in the Gambia. Therefore, climate change in which mean annual rainfall as a proxy variable upset positively all the four pillars of food security in the long-run. This result is insignificant. Similarly, to the short-run, economic growth in which GDP current is the proxy variable in long term has unimportant and negative effect on food security. As GDP per capital make available standard of living. Overall, per capital GDP has adverse impact on food security in the long run. So GDP per capita in the Gambia does not translate to our standard of living due to Insufficient GDP with more population associate to developed nations like Norway and Canada.

ECM(-1) = -0.7201, P-value = 0.0145, Standard error in parenthesis = (0.2811) and t-statistic = -2.5616.From having found out these results from error correction model(ECM) representation and having found out from the unit root tests the variables in the model are stationary at the first differences, I(1) and cointegrated ARDL F- bound test approaches. Varsoc applied with sufficient of 3 lags with AIC criteria selected due to the minimum value the better for the model.The ECM permits the long term conduct of the dependent variable to meet to long run equilibrium association, whereas agreeing a wider variety of short-run dynamics coefficients. In other word, the ECM comprises the long-run variables being assessed and it runs with short-run variables.The coefficient of ECM term with lag 1 for the log of food security as dependent variable carries an appropriate sign (-0.7201). It is statistically important at 1 % alpha and has positive coefficient absolute term and lied between 0 and -1. The speed of change to equilibrium is 72 % (see Table 17). It is confirming the stability of the model from the diagnostic tools test conducted such as cumsum, cumsum square, recursive

test, LM test for serial correlation and normality test for the residual. As large absolute value from the coefficients on the ECM confirmed that equilibrium agents remove a long-run disequilibrium in each period from 1971 to 2020. Importance the speed of adjustment is very quick. The little speed of adjustment to equilibrium means slight absolute value of the ECM. It means that in our model when the dependent variable is food security, the speed of adjustment towards the equilibrium is very quick i.e. 72 %. It is very fast to remove disequilibrium and to adjust to equilibrium. Finally, it means that food security will be rapidly to reach at the equilibrium after the innovation that touch it due to climate change variability and poor economic performance, poor agriculture and so on.

Conclusion and Policy recommendation

The paper investigate between climate change, food security, economic growth, population growth rate, agriculture value added, and GDP per capita. The results found that agriculture has positive correlation with food security in the Gambia. Change in the average annual rainfall has significant and negative impact on food security. The GDP per capita has positive impact on food security in the first period lags and negative impacts on food security in the second period lags. However, shocks to food security will require a slightly optimistic influence on agriculture sector in the short-run and considerably negative impact on the long-run. Food security shocks will also lead to poor agriculture in the long term. Food security and GDP per capita as unidirectional relationship. In the similar vein, short term demonstrations that a variation in the growth of food security on it owns lag is significant and negative. Agriculture sector is significant adverse impact on food security. A 100 % rise in agriculture sector growth results to an increases of growth of food security by 0.0704 %. A percentage growth in population yearly there is a fall in food security by 0.033 %. Finally, the error correlation part of the ARDL model found that, the coefficient of the

ECM term at lag 1 for the log of food security as dependent variable carries an appropriate sign (-0.7201). It is significant at 1 percent of alpha and has positive coefficient absolute term and lied between 0 and -1. Policy recommendation is that since agriculture is important for food security in the rural Gambia. The government should work on planting more trees for better agriculture and environment, Food security intervention programs, and Poverty reduction programs, provision of more adaptive capacity indicators, Quality and affordable education for all, System changes to bring quality of governance and institution and economic that is working for all and sundry, and consider export economy. The government food security intervention should also include two important institutional characteristic such as access to credit and access to agriculture extension service by farmers in order to have grants or loans to buy new agriculture technologies and to have new education or training to translate the food system in the Gambia, the author noted.

Compliance With Ethical Standards.

Ethic statement:

This article does not comprise any studies with human contributors or animals performed by any of the authors.

Availability of data.

Dataset evaluated in this article is accessible from the corresponding author on sensible request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

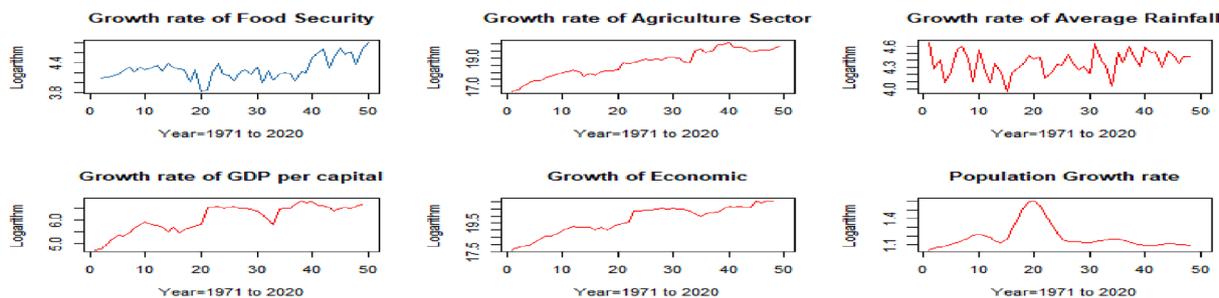


Fig. 6. ARDL Non-stationary variables at the level.

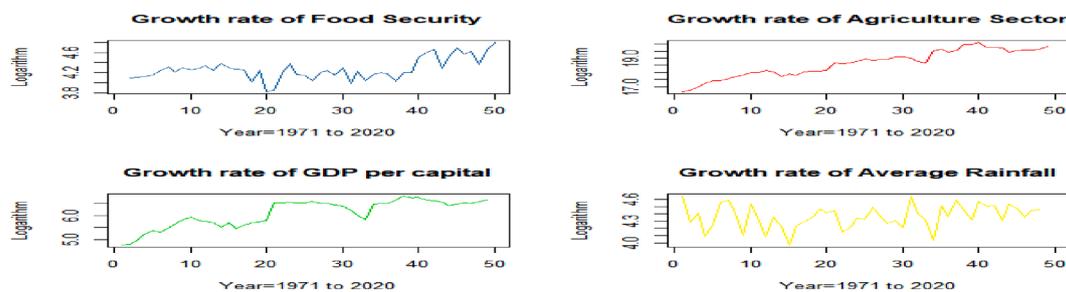


Fig. 7. VAR Non-stationary at the level.

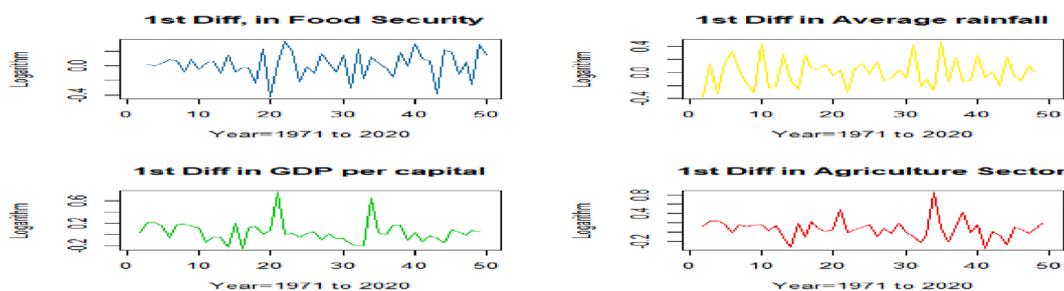


Fig. 8. VAR Stationary at the first differences.

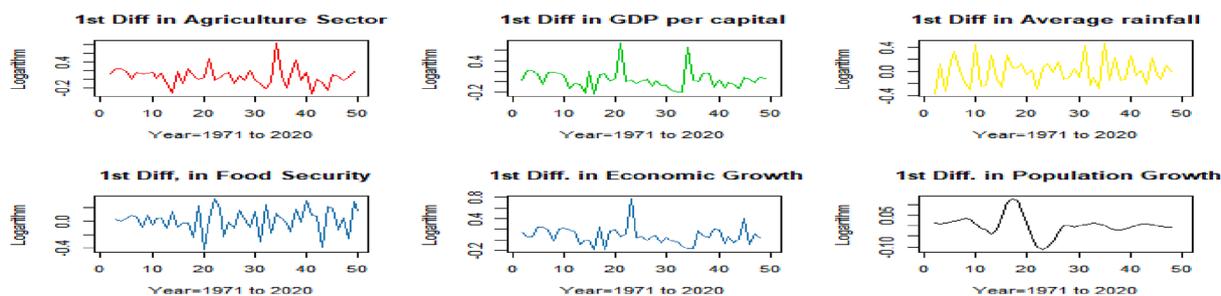


Fig. 9. ARDL stationary at the first differences.

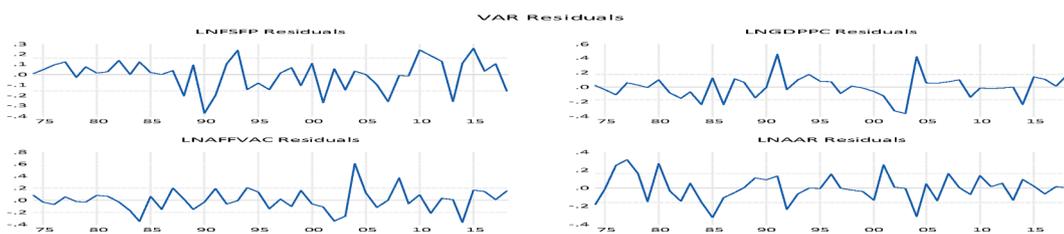


Fig. 10. VAR residuals.

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