Innovations

Agricultural productivity, population growth and food security in sub-Saharan Africa

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Abstract: *The study investigates the impact of Agricultural productivity and population growth on food security in Sub-Saharan Africa from 2001 to 2019. The study made use of secondary data sourced from the World Development Indicator (WDI, 2021), and the Food and Agricultural Organization of the United Nations (FAO, 2021). A sample of 38 countries out of the 48 countries in Sub-Saharan Africa was selected using convenient sampling technique. Food security, the dependent variable was measured in terms of availability, accessibility, stability and Utilization, proxied by "Food production Index (2006=100)", "Gross domestic product per capita, PPP, Dissemination (constant 2011 international $)", "Per capita food supply variability (kcal/cap/day)" and "Percentage of population using at least basic drinking water service" respectively. In other to achieve the objective of the study, the System Generalised Method of Moments (GMM) was employed. From the GMM result, agricultural productivity with coefficients of 0.07064, 0.04724, 0.45007 and 0.05036 positively and significantly impacted food security when measured in terms of Availability, Accessibility, Stability and Utilization respectively. While population growth with coefficients of -0.09528, -0.03628, -0.74364 and -0.03867 negatively and significantly impacted food security when measured in terms of Availability, Accessibility, Stability and Utilization respectively. The study based on its findings recommended that African leaders need to play a critical role in supporting agricultural research and development which will increase agricultural productivity and hence improves food security.*

Keywords: ***1.****Agriculture, 2.Food security, 3.Productivity, 4.Population growth****, 5.****Sub-Saharan Africa.*

JEL Classification*: Q10, Q56, Q18, O55*

1. Introduction

Food security is described as "having physical, social, and economic access to an adequate, healthy, and nourishing diet that meets their dietary needs and food fondness for a healthy and balanced life at all periods" (FAO, 2010). Also, according to Enilolobo et al, (2022a),food security is a measure of food availability, acceptability and affordability.Many people regard it as afundamental human right but nearly one billion individuals worldwide, especially in food-deficit and low-income underdeveloped nations, continue to suffer from extreme poverty and malnutrition (IEG, 2011).After the rise in world food prices in 2007–2008, food security has remained one of the top issues on the global improvement agenda. This is shown by the global community's intense interest in the topic and during the development of the 2030 Roadmap, the international agenda that established the collection of Sustainable Development Goals (SDGs); SDG 2 focuses solely on food security, acknowledging much of its dynamic, multifaceted complexity.

Food security, according to Agboola (2014), is a condition for healthy living. The importance of food security in terms of labour efficiency cannot be overstated. It contributes to economic and political stability; the inability to ensure food security, on the other hand, promotes starvation, malnutrition, and unnecessary food importation, which leads to a trade imbalance (Havas & Salman, 2011; Candel, 2014).
The amount of agricultural productivity growth in a country partially reflects the status of food security in that economy. Efficient agricultural policies aimed at maintaining long-term food stability in Sub-Saharan Africa (SSA) are thus critical for poverty alleviation and substantial economic development (Collier &Dercon, 2014; Conceiço et al., 2016).
Agricultural productivity growth could have a big impact on food security since it is one of the few opportunities to increase food production while keeping prices down. Since the 1960s, improving agricultural productivity has been extremely important to poverty lessening around the world (Dercon& Gollin, 2014; Pingali, 2012). SSA, on the other hand, has earned fewer gains from past investments than other regions and, by international benchmarks, continues to have low agricultural productivity (GYGWPA, 2017). According to Chauvin et al.,(2012), agricultural success in SSA has not met its potential, with ups and downs over the decades (FAO, 2005). Low production and miniature application of science and technology characterize agriculture in Sub-Saharan Africa. Conferring to the UN's Food and Agriculture Organization (FAO), one out of every four Africans does not have enough food to live a happy and healthy life (Bremner, 2012).While some African nations have met Millennium Development Goals (MDGs) such as "terminating extreme poverty and hunger" and "halving the proportion of individuals who are hungry by 2015, the general picture for Africa is mixed, with sluggish progress overall (FAO, 2015).
Shuttering agricultural productivity gaps will be insufficient to guarantee that food supply keeps pace with increasing demand (Van-Ittersumet al., 2016).For SSA to achieve food security, and improved agricultural output, in conjunction with a growing population and a well-developed manufacturing sector, as well as economic and political stability, is critical. However, we acknowledge that unless major improvements are taken to ensure food security in Africa in the immediate future, the problems will only worsen.

2. Literature Review

Enilolobo et al., (2022b), investigated food security in Africa; the role of agricultural import and export. The study utilised secondary data sourced from the World Data Banks from 1980 to 2019 on ten African countries. The autoregressive distributed lag (ARDL) model and Dumitrescu Hurlin panel causality test were adopted in the evaluation of the study hypotheses. The result reveals that agricultural exports (AGREXP) have a negative and insignificant impact on food security in selected African countries while agricultural imports (AGRIMP) have a positive and significant impact on food security. The study recommended that, given the rapid urbanization in Africa, agricultural imports and trade liberalization should be further used to boost food security to achieve the sustainable goal of zero hunger in African cities.
Khalid et al., (2021) examined Social Inclusion, Innovation and Food Security in West Africa. The study examined how innovation and social inclusion affect food security in West Africa. The study applied the system Generalised Method of Moments (GMM) on panel data from 15 West African countries for the period 2005–2018. The result from the system GMM shows that innovation and social inclusion are drivers of food security. Therefore, the study concluded that to feed the growing African population, social inclusion should be improved to mitigate risk, vulnerability and socioeconomic shocks faced by farming households. In addition, innovation in agriculture should be enhanced to drive productivity, thereby leading to sustainable food security.
Bjornlund and Van-Rooyen (2020) looked at why agricultural production in SSA continues low in comparison to the rest of the world from a historical standpoint. The study found that agricultural output in Sub-Saharan Africa has stayed lesser than the rest of the world in recent years. Climate, soil quality, slavery, and disease are all factors that are implicit to Africa and its people.

Oguntegbe et al., (2018) used secondary data on the food production index and population growth rate from 1980 to 2011 to evaluate population growth difficulties and food security in Nigeria. The model was estimated using both the Ordinary Least Square regression and the Instrumental Variable technique. Population growth is directly linked to food production, according to empirical findings from the OLS. The Instrumental Variable Approach, on the other hand, yielded a more intriguing finding: an increase in population growth rate reduces food output significantly. Nigeria must consequently control its population growth rate in an attempt to evade population outbursts and the ramifications that come with them.

Ogunlesi and Bokana (2018) probed the Dynamics of Agricultural Productivity in SSA: A P-ARDL Model Approach. Using the recent Panel ARDL, the study empirically explored the long- and short-run dynamics of agricultural output in 37 carefully chosen countries in SSA between 1990 and 2016. The model showed a cointegrating connection between agricultural output and the independent variables, but no short-run strong connection. The study discovered that workforce and the real exchange rate have a positive and noteworthy long-run effect on agricultural productivity, whereas capital, openness, and per-capita income have an adverse but significant impact. Based on these findings, appropriate macroeconomic policies to maintain the exchange rate, encourage exports, maximize capital utilization, and improve infrastructure availability are recommended to stimulate agricultural productivity and spur economic growth in SSA.

Sheng et al., (2017) incorporated the accounting framework to scientifically quantify capital and labour's concession to agricultural productivity in Australia from 1949 to 2012. The analysis revealed that capital yields better proceeds than labour, implying that fluctuating input and output efficiencies appear to boost agricultural productivity in the region.

Akandeet al., (2017) scrutinized the association between agricultural exports and productivity in SSA nations, using stochastic regression appraisal between 1981 and 2005. Increased exports hurt agricultural volume, according to the scholar, who endorses regulations that foster exports and institutional reliability to boost agricultural productivity even more.

Adopting the system GMM method, Dithmer and Abdulai (2017) investigated the impact of trade openness on food security using a large cross-country dataset. In line with economic theory, the finding shows that economic openness to trade has a positive and significant relationship with dietary consumption, diversity and quality. Therefore, the authors recommended that policies supporting trade liberalization should be encouraged to improve food security.

Ogundari and Awokuse (2016) validated the Influence of agricultural productivity on food security thresholds in sub-Saharan African countries. In Sub-Saharan Africa, the study looked at the influence of agricultural productivity on various food security measures (SSA). They used both dynamic and linear models to analyse panel data from 41 countries from 1980 to 2009.Both models' empirical results show that increasing agricultural productivity has a direct and noteworthy influence on all of the study's food security measures. As a result, it appears that increasing SSA's current rate of agricultural productivity growth is a vital component of improving food security. As a result, they argue that policies aimed at expanding government investment in agricultural research and development (R&D) would likely boost agricultural productivity and, as a result, regional food security.

Muzari (2016) looked into SSA agricultural productivity and food security. The study discovered that the rural population in SSA has been unable to escape poverty and food insecurity due to their inability to renovate their primary economic activity, agriculture. Particularly, productivity remains well underneath the region's produce prospects, agricultural mechanization is flawed and shrinking, and the agribusiness industry is still in its infancy

3. Methodology

Theoretical Framework

The theoretical framework for this study centres on labour surplus theory, which was formulated in 1954 by Arthur Lewis. The theory recognizes that agriculture provides the surplus needed for achieving growth. However, the theory explains that surplus can be actualized via labour supply. Lewis (1954) argues that when excess labour is withdrawn from the casual sector of the economy to the formal/current sector they are being utilized. Lewis recognizes the relevance of capital investments in the development of the agricultural sector. That is, mechanization of the agricultural sector helps to sustain productivity.The methodology made use of a regression model built from Arthur Lewis's dual sector theory, which is a pro-agricultural theory that relies on how to promote agricultural productivity. The theory can be traced as far back as eighteenth-century studies of the Physiocrats, who asserted that agriculture produced the net surplus that ignited economic growth. The physiocrat school of thought was unable to justify how to attain the necessary net surplus for economic affluenceThis was subsequently clarified by Lewis' (1954) theory, which stated that by transferring surplus labour from the informal to the formal/current sectors of the economy, marginal labour productivity is boosted via the use of capital. As productivity rises, revenues rise as well, resulting in enhanced welfare and poverty reduction. Based on this theoretical framework, this study notes that Population Growth and agricultural productivity are necessary to ensure food security in sub-Sahara Africa.

Model Specification

To analyze the research objective of this study, the model of Oguntegbe et al., (2018) is adapted and expressed below;

□□□ = □0 + □1□□ + □2□□□□ + □3□□ + □□…………………………………………………………… (1)

Where: FP_t = Food Production (food production index)

ρ_t = Population growth rate

γ_t = GDP per capita (It is logged to prevent it from being an outlier since all other variables are ratios)

ω_t = Arable land per person (hectares per person)

ε_t = Error term

In other to achieve the objectiveof this study equation one will be specified as follow;

FS_i= f(x)

$FS_i = f(AP, PG, CO_2)$…………………………………………………………………………………(2)

i = 1, 2, 3 & 4

Where;

FS_i= food security dimensions

1 = (Availability (AV)) proxied by "Food production Index (2006=100)"

2 = (Accessibility (AC)) proxied by "Gross domestic product per capita, PPP, Dissemination (constant 2011 international $)"

3 = (Stability (ST)) proxied by "Per capita food supply variability (kcal/cap/day)"

4 = (Utilization (UT)) proxied by "Percentage of population using at least basic drinking water service"

AP = Agricultural productivity proxied by "agriculture, forestry and fishing, value added (% of GDP)

PG = Population growth (annual %)

CO_2= CO_2 emissions in Metric tons

From equation 2;

$$AV = \beta_{0it} + \beta_1 PG_{it} + \beta_2 AP_{it} + \beta_3 CO_{2it} + U_{it} \quad (3)$$

$$AC = \alpha_{0it} + \alpha_1 PG_{it} + \alpha_2 AP_{it} + \alpha_3 CO_{2it} + U_{it} \quad (4)$$

$$ST = \infty_{0it} + \infty_1 PG_{it} + \infty_2 AP_{it} + \infty_3 CO_{2it} + U_{it} \quad (5)$$

$$UT = \theta_{0it} + \theta_1 PG_{it} + \theta_2 AP_{it} + \theta_3 CO_{2it} + U_{it} \quad (6)$$

Where;

$\beta_0, \alpha_0, \infty_0$ & θ_0 are the intercept of the models; $\beta_1, \alpha_1, \infty_1$ & θ_1 to $\beta_3, \alpha_3, \infty_3$ & θ_3 = Parameter Estimates; U = Stochastic Disturbance Error Term; i = country; t = time.

Estimation Techniques

Given that the number of cross-sectional observations is substantially higher than the number of periods (i.e., large N and small t); the General Method of Moments (GMM) estimation technique would be optimal. The GMM technique, compared to the OLS method, can resolve the endogeneity and heteroskedasticity problems and improve the performance of estimators in a panel model (Headey, 2013). Furthermore, this study engages the robust version of the System-GMM (SYS-GMM) estimating model modified by Blundell and Bond (1998), which is an improvement on the GMM approach, by the inclusion of the instrumental variables (IV), hence, our reason for the choice of the model. The advantage of the SYS-GMM over the GMM model is that it overcomes the challenge of weak IV arising in the GMM model, making them more dynamically efficient. It follows the assumption of exogeneity of dynamic constant correlation among endogenous variables and unobserved fixed effects, thus factoring the linearity function of the lagged IV at both level and difference. In this regard, the SYS-GMM estimator of the dynamic panel model is preferred above the linear or static model as it allows for causality via the IV by assuming there is no correlation among random shock in the present period error term, the lagged dependent variable and the present variable (Kunst et al.,2016). Therefore, equations (3) to (6) will be specified to form the GMM models as follows;

$InAV = \beta_{0it} + \Omega InAV_{it-1} + \beta_1 InPG_{it} + \beta_2 InAP_{it} + \beta_3 InCO_{2it} + U_{it}$ …………………. (7)

$InAC = \alpha_{0it} + \partial InAC_{it-1} + \alpha_1 InPG_{it} + \alpha_2 InAP_{it} + \alpha_3 InCO_{2it} + U_{it}$ ……………….. (8)

$InST = \infty_{0it} + ? InST_{it-1} + \infty_1 InPG_{it} + \infty_2 InAP_{it} + \infty_3 InCO_{2it} + U_{it}$ ……………… (9)

$InUT = \theta_{0it} + \Phi InUT_{it-1} + \theta_1 InPG_{it} + \theta_2 InAP_{it} + \theta_3 InCO_{2it} + U_{it}$ ………………… (10)

Where; Ω, ∂, ƌ, & Φ are the coefficient of the first-lag of the dependent variables in equations7 to 10 respectively.

Serial Correlation Test: The appropriate test statistic for GMM regressions on panels is the Arellano-Bond Serial Correlation tests AR(1) and AR(2) under the hypothesis that serial correlation does not exist. According to Roodman (2009), it is expected that the hypothesis of the nonexistence of serial correlation of order one AR(1) is rejected while the null hypothesis of the nonexistence of serial correlation of order two AR(2) is expected to be accepted.

Instrument Validity Test: A very important assumption for the validity of GMM is that the instruments are exogenous and valid. This is because in sGMM, the endogenous variable that is among the explanatory variables is proxy by instrumental variables to correct for endogeneity and there is a need to check whether the instruments are valid. The Hansen (1982) J test for over-identifying restrictions with the null hypothesis that 'instruments are valid' was used to examine this. The null hypothesis is to be accepted to establish the validity of the instruments.

Sampling Technique

The population of this study is the 48 countries in Sub-Sahara Africa. However, the convenient sampling technique was adopted based on data availability. Using the convenient sampling technique, a total of 38 countries in SSA were selected. The selected countries includeAngola; Benin; Botswana; Burkina Faso; Cabo Verde; Cameroun; Chad; Congo; Cote d'Ivoire; Eswatini; Ethiopia; Gabon; Gambia; Ghana; Guinea; Guinea-Bissau; Kenya; Lesotho; Liberia; Madagascar; Malawi; Mali; Mauritania; Mauritius; Mozambique; Namibia; Niger; Nigeria; Rwanda; Sao Tome; Senegal; Sierra Leone; South Africa; Togo; Uganda; United Republic of Tanzania; Zambia; and Zimbabwe.

Description of variables and Sources of Data

Table 3.1 Description of variables and Sources of Data

Variables	Description and measurement of the variable	Source of data
	Dependent Variables (Food Security (FS))	
1. Availability (AV)	Food production index (2004-2006 = 100): **Food production index** covers **food** crops that are considered edible and that contain nutrients.	WDI 2021
2. Accessibility (AC)	measured by "Gross domestic product per capita, PPP, Dissemination (constant 2011 international $)"	FAO 2021
3. Stability (ST)	measured by "Per capita food supply variability (kcal/cap/day)"	FAO 2021
4. Utilization (UT)	measured by "Percentage of population using at least basic drinking water service"	FAO 2021
	Independent Variables	
1. PG	Population growth: Population growth is the increase in the number of individuals in a population	WDI 2021
2. AP	Agricultural productivity (Proxied by Agricultural value added): Agricultural productivity is measured as the ratio of agricultural outputs to agricultural inputs	WDI 2021
	Control Variable	
1. CO_2	CO_2emissions: Carbon dioxide emissions are emissions stemming from the burning of fossil fuels and the manufacture of cement; they include carbon dioxide produced during consumption of solid, liquid, and gas fuels as well as gas flaring.	Global Carbon Atlas 2020

Source: *Author's Computation (2021)*

4. Results and Discussion

Descriptive Statistics

Table 4.1: Summary Statistics of Variables

	AV[a]	AC	ST	UT[b]	PG[b]	AP[b]	CO_2
Mean	87.591	4187.565	39.215	62.498	2.460	22.375	18.851
Median	92.495	2620.400	34.000	62.800	2.678	22.691	2.754
Maximum	133.940	22989.30	215.000	99.900	4.630	79.042	502.259
Minimum	33.190	687.100	4.000	20.300	-0.617	1.828	0.051
Std. Dev.	18.645	4172.121	24.766	15.927	0.873	14.094	73.629
Skewness	-0.564	2.021	1.840	0.022	-1.042	0.702	5.504
Kurtosis	2.535	6.542	8.644	2.757	4.028	3.494	32.792
Jarque-Bera	44.751	869.099	1365.663	1.829	162.550	66.652	30345.41
Probability	0.000	0.000	0.000	0.401	0.000	0.000	0.000
Observations	722	722	722	722	722	722	722

a -Figures in Index

b- Figures in Percentage

Sources: *Author's Computations (2021)*

Skewness is a statistical analysis that is employed to measure the departure from symmetry. A distribution or data set is said to be symmetric if it is spread out evenly to the left and right of the centre point; in such an instance, skewness is zero. Positive values for skewness indicate data that are skewed right or positively skewed, while negative values indicate data that are skewed left or negatively skewed (Gujarati, 2003). From the table above however, two variables (AV and PG) with values of -0.564 and -1.042 are negatively skewed, while five variables (AC, ST, UT, AP and CO_2) with values of 2.021, 1.840, 0.022, 0.702 and 5.504 respectively are positively skewed.

Kurtosis measures the degree of peakedness or flatness of data relative to data normal distribution. The normal distribution has a kurtosis of 3. Excess kurtosis (Ex. kurtosis) is simply defined as kurtosis minus 3 (i.e., kurtosis – 3). Ex. kurtosis for the normal distribution is therefore 0 (i.e., 3 - 3 = 0). The normal distribution is a symmetric distribution with kurtosis of 3 or Ex. kurtosis of 0. A distribution with kurtosis or Ex. kurtosis above that of the normal distribution indicates data that are peakedness or lapto-kurtic, while a distribution with kurtosis or Ex. kurtosis below that of the normal distribution indicates data that are flat or plato-kurtic. A distribution with kurtosis or Ex. kurtosis at normal distribution is mesokurtic. In other words,a distribution with kurtosis > 3 or Ex. kurtosis > 0 indicates data that are peakedness or laptokurtic, while a distribution with kurtosis < 3 or Ex. kurtosis < 0 indicates data that are flat or plato-kurtic. A distribution with kurtosis of 3 or Ex. kurtosis of 0 is mesokurtic (Gujarati, 2003). The kurtosis for variables AC, ST, PG, AP and CO_2 are all greater than 3, i.e., 6.542, 8.644, 4.028, 3.494, and 32.792, respectively, indicating that the distributions are peaked relative to data normal distribution or lapto-kurtic. While kurtosis for variable AV and UT are all less than 3. i.e., 2.535 and 2.757, respectively indicating that the distributions are flat relative to data normal distribution or plato-kurtic.

Finally, the Jarque-Bera statistics rejected the null hypothesis of normal distribution for AV, AC, ST, PG, AP and CO_2 at 5% critical value, while it accepted the null hypothesis of normal distribution for UT at 5% critical value.

Correlation Matrix Analysis

Table 4.2: Correlation Matrix

	AV	**AC**	**ST**	**UT**	**PG**	**AP**	**CO_2**
AV	1.00						
AC	0.25	1.00					
ST	0.04	0.04	1.00				
UT	0.38	0.68	0.10	1.00			
PG	-0.29	-0.44	-0.13	-0.54	1.00		
AP	-0.24	-0.63	-0.02	-0.53	0.49	1.00	
CO_2	0.03	0.32	-0.16	0.27	-0.18	-0.24	1.00

Sources: *Author's Computations (2021)*

Table 4.2 above shows the result of the correlation matrix analysis. The correlation coefficient between PG and AP is 0.49 indicating a weak positive relationship between PG and AP. Also, the correlation coefficient between PG and CO_2 is -0.18 indicating a weak negative relationship between PG and CO_2. Similarly, the correlation coefficient between AP and $CO_2$is -0.24 also indicating a weak indirect relationship between AP and CO_2

Using the correlation matrix as shown in Table 4.2, there is no problem of multicollinearity since the correlation coefficients of all the variables are lower than the recommended threshold of more than 0.8. As a rule of thumb, Gujarati (2003) suggested that if the correlation > 0.8 then severe multicollinearity may be present.

Estimates from One step System Generalised Method of Moments

Table 4.3: One-Step System GMM Results of the estimated models (equations 7 to 10).

	Dependent ln AV	**Dependent ln AC**	**Dependent ln ST**	**Dependent ln UT**
Variables	**Equation 7**	**Equation 8**	**Equation 9**	**Equation 10**
In y (-1)	0.9959* (0.000)	0.99951* (0.000)	0.9936* (0.000)	0.91134* (0.000)
In AP	0.07064* (0.002)	0.04724* (0.000)	0.45007** (0.006)	0.05036* (0.000)
In PG	-0.09528** (0.005)	-0.03628* (0.000)	-0.74364* (0.004)	-0.03867* (0.000)
In CO_2	-0.07562 (0.075)	-0.02512* (0.000)	-0.13066* (0.004)	-0.01257* (0.000)
Constant	0.3384 (0.187)	0.11659 (0.303)	1.9259* (0.002)	0.45881* (0.000)
No. of observation	678	678	678	678
No. of Groups	38	38	38	38
Wald chi^2	1874.43* (0.000)	254330.12* (0.000)	516.14* (0.000)	345327.60* (0.000)
AR(1)	-10.54* (0.000)	-7.32* (0.000)	-7.01* (0.000)	-4.05* (0.000)
AR(2)	2.41 (0.160)	-2.45 (0.104)	-1.79 (0.073)	1.04 (0.298)
Hansen Test	2.67 (0.102)	1.07 (0.301)	2.02 (0.155)	0.33 (0.565)

Note: In y (-1) show the lag of ln AV, ln AC, ln ST, & ln UT. **Source:** *Author's computation (2021)* & **, represent significance at 1%, and 5% levels of significance.* ***Note**: Values in parenthesis are P-values.*

From table 4.3 (**estimation of equation 7**), the coefficient of the lagged value of the dependent variable (AV) is 0.9959 and it's statistically significant at 1%. Also, the coefficient of AP is 0.07064 with a p-value < 0.01 indicating that there exists a direct and significant relationship between AP and food security when measured in terms of Availability (AV). The value of the coefficient implies that a percentage increase in AP will cause the dependent variable AV to increase by 7.064% in the short-run ceteris paribus and vice-versa. Similarly, the coefficient of PG is -0.09528 with a p-value<0.05 indicating that there exists an indirect and significant relationship between PG and the dependent variable AV, implying that a percentage increase in PG will cause the dependent variable AV to reduce by 9.528% in the short-run ceteris paribus.

From table 4.3 (**estimation of equation 8**), the coefficient of the lagged value of the dependent variable (AC) is 0.99951 and it's statistically significant at 1%. Also, the coefficient of AP is 0.04724 with a p-value < 0.01 indicating that there exists a direct and significant relationship between AP and food security when measured in terms of Accessibility (AC). The value of the coefficient implies that a percentage increase in AP will cause the dependent variable AC to increase by 4.724% in the short-run ceteris paribus. Also, a percentage decrease in AP will cause the dependent variable AC to decrease by 4.724% in the shortrun. Similarly, the coefficient of PG is -0.03628 with a p-value<0.01 indicating that there exists an indirect and significant relationship between PG and the dependent variable AC, implying that a percentage increase in PG will cause the dependent variable AC to reduce by 3.628%in the short-run ceteris paribus.

From table 4.3 (**estimation of equation 9**), the coefficient of the lagged value of the dependent variable (ST) is 0.9936 and it's statistically significant at 1%. Also, the coefficient of AP is 0.45007 with a p-value < 0.01

indicating that there exists a direct and significant relationship between AP and food security when measured in terms of Stability (ST). The value of the coefficient implies that a percentage increase in AP will cause the dependent variable ST to increase by 45.007%in the short-run ceteris paribus. Likewise, a percentage decrease in AP will cause the dependent variable ST to decrease by 45.007%in the shortrun. Similarly, the coefficient of PG is -0.74364 with p-value<0.01 indicating that there exists an indirect and significant relationship between PG and the dependent variable ST, implying that a percentage increase in PG will cause the dependent variable ST to reduce by 74.364% in the short-run ceteris paribus.

From table 4.3 (**estimation of equation 10**), the coefficient of the lagged value of the dependent variable (UT) is 0.91134 and it's statistically significant at 1%. Also, the coefficient of AP is 0.05036 with a p-value < 0.01 indicating that there exists a direct and significant relationship between AP and food security when measured in terms of Utilization (UT). The value of the coefficient implies that a percentage increase in AP will cause the dependent variable UT to increase by 5.036% in the short-run ceteris paribus and vice-versa. Similarly, the coefficient of PG is -0.03867 with p-value<0.01 indicating that there exists an indirect and significant relationship between PG and the dependent variable UT, implying that a percentage increase in PG will cause the dependent variable UT to reduce by 3.867% in the short-run ceteris paribus.

Similarly, according to Roodman (2009), it is expected that the hypothesis of the nonexistence of serial correlation of order one AR(1) is rejected while the null hypothesis of the nonexistence of serial correlation of order two AR(2) is expected to be accepted. From the estimated models, the values of AR (1) for the four models are -10.54, -7.32, -7.01, and -4.05 respectively are all significant at 1% hence the hypothesis of the nonexistence of serial correlation of order one AR(1) is rejected. While the values AR (2) for the four models are 2.41, -2.45, -1.79 and 1.04 respectively and are insignificant at a 5% level of significance hence the null hypothesis of the nonexistence of serial correlation of order two AR (2) is accepted.

Also, the probability value of the Hansen J test for the models is 0.102, 0.301, 0.155, and 0.565 respectively which are all greater than 0.05 indicating that the application of the Hansen J test of over-identifying restriction did not support the rejection of the validity of the instruments hence indicating that the instruments used are valid.

Lastly, the Wald Chi-square for the estimated equations 10 to 13 is 1874.43, 254330.12, 516.14, and 345327.60 which are all significant at 1% i.e., p<0.01 indicating that all the independent variables in the model have a joint significant impact on the dependent variable.

Discussion of findings

From the One Step System GMM Result presented in table 4.3, it is evident that Agricultural productivity and Population growth both significantly impact Food security (when proxied for Availability (AV), Accessibility (AC), Stability (ST) and Utilization (UT)). From the results in table 4.4, Agricultural productivity has a direct and significant relationship with all measures of food security in SSA. The finding of a direct and significant relationship between Agricultural productivity and food security (AV, AC, ST, and UT) is in conjunction with the findings of Ogundari and Awokuse (2016) and Ogunlesi and Bokana(2018) who asserted that Agricultural productivity contributes positively and significantly to food security. Although Agricultural Productivity contributes positively to food security in SSA, Agricultural productivity in the region has been relatively low and performance is below expectation. Also, according toMuzani(2016), Agricultural productivity in SSA is way below the region's yield potential, agricultural mechanization is weak and declining, and the size of the Agric-business industry is still nascent. This is also supported by Chauvin et al., (2012) who asserted that Agriculture in SSA is marked by low productivity with little application of science and technology.

The result from table 4.4 also shows that population growth has an indirect significant impact on food security (AV, AC, ST and UT). This finding is in support ofOguntegbe et al., (2018) who found that an increase in PG significantly reduces food output when the instrumental variable approach was employed. A notable reason for the inverse relationship between Population growth and Food security is that land is available in fixed limited quantity and as population growth increase so does the demand for land increase for other purposes such as the construction of road, houses, hospital, schools, etc. thereby reducing the available land for agricultural purpose and hence reduction in food security.

The study also found out that CO_2 emissions have an indirect and significant impact on food security (AC, ST and UT) but an indirect and insignificant impact on food security (AV). The finding of an indirect relationship between CO_2 and food security is in conjunction with the finding of Edoja et al., (2016) who also found that CO_2 emission has a significant negative impact on food security.

5. Conclusion

This study carried out empirical research to investigate the impact of Agricultural production and population growth on food security in Sub-Saharan Africa from 2001 to 2019. Food security, the dependent variable was measured in terms of availability, accessibility, stability and Utilization, proxiedby "Food production Index (2006=100)", "Gross domestic product per capita, PPP, Dissemination (constant 2011 international $)","Per capita food supply variability (kcal/cap/day)" and "Percentage of population using at least basic drinking water service"respectively. From the GMM results, the study concludes that population growth has an indirect significant relationship with all measures of Food Security (AV, AC, ST, and UT). Agricultural Productivity also has a direct and significant relationship with all measures of Food Security (AV, AC, ST, and UT) while CO_2 emissions have an indirect and significant impact on food security (Accessibility, Stability and Utilization), but an indirect and insignificant impact on food security (Availability). The study, therefore, concludes that both agricultural productivity and population growth have an impact on food security SSA.

6. Recommendations

Based on the findings of this study, the following recommendations were made

- The government of nations in SSA should consider investing more funds inthe agricultural sector (especially in Agro base Research and Technology), in its statutory allocation, by so doing the sector will have enough to put into use in other to boost agricultural productivity in the region.
- Population checks (Family planning) should be encouraged and people should be enlightened on the negative impact of population growth on food security in the Region.
- The government of Countries in Sub-Sahara Africa should embrace industrialization in other to increase the value of Agricultural output at a reduced cost as this will in turn improve food security in the region.
- CO_2 emission should be frowned upon and policies to reduce the emissions of CO_2 should be put in place given its negative impact on Food security.
- African leaders should play a critical role in supporting science and innovation onwhich increased agricultural productivity, which improves food security depends.

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