Inequality, population growth, and hunger in Sub-Saharan Africa

Sakiru Oladele Akinbode1 · Peter Adebola Okuneye2 · Chukwuka Oluwatobi Onyeukwu1

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Abstract
Despite increasing population and inequality in most countries in Sub-Saharan Africa (SSA) and their tendencies to aggravate hunger there is still dearth of knowledge on their effects on hunger in the region. Therefore, the study used data for 46 SSA countries from 2007 to 2017 to examine the effects of inequality and population on hunger by adopting the System Generalized Method of Moment approach as it is specifically applicable in this situation. Results showed that inequality ($p < 0.01$) and population growth ($p < 0.1$) significantly increased the level of hunger, while GDP per capita ($p < 0.01$) and Food Production index ($p < 0.1$) significantly reduced hunger in the region. Arellano–Bond test confirmed the validity of the GMM results by rejecting the null hypothesis of non-existence of autocorrelation of the first order and accepting that of the second order in the disturbance term, while the Hansen and Sargan tests affirmed that variables used as instruments were valid in line with expectations. Robustness of the result was also confirmed as the coefficient of the lagged response variable (0.8701) fell between the fixed effect model estimate (0.5165) and pooled OLS estimate (0.9571) in line with theory. The study recommended policies capable of reducing inequality, boosting economic growth, and controlling excessive population growth, while food production and value addition are encouraged in order to avert hunger in the region.

Keywords Inequality · Population · Hunger · Sub-Saharan Africa (SSA)

Sakiru Oladele Akinbode
akinbodeso@funaab.edu.ng; deleakinbode@yahoo.com

1 Department of Economics, Federal University of Agriculture, P.M.B. 2240, Abeokuta, Nigeria
2 Department of Agricultural Economics and Farm Management, Federal University of Agriculture, P.M.B. 2240, Abeokuta, Nigeria
Introduction

In the Abraham Maslow’s popular hierarchy of need, the basic physiological need (food) is the first after which clothing and shelter follow. This shows the importance of food as a human being cannot survive for long without food. It is conventional for health workers to advise patients to take their drugs after meal. This underscores the superiority of food over drug as a requirement to attain sound health. In fact, food has at one time or the other been used as instrument to weaken opponents and win wars. As opined by the National Research Council (2006), hunger describes a phenomenon of a short period physical uneasiness which occurs due to persistent lack of sufficient food or in some serious situation, lack of food which may be fatal. Unarguably, the most obvious expression of hunger is a diet not enough to keep someone healthy (Barrett and Lentz 2016). Hunger has been the bane of humanity to the extent that “zero hunger” was the second among the seventeen goals of the 2030 Agenda for Sustainable Development which was the outcome of the UN summit held at the UN Headquarters in New York in September 2015. It is worthy of note that related terms to hunger include but not limited to malnutrition and food insecurity. Malnutrition is the manifestation as a result of inadequate consumption of physiologically needed nutrients, while food insecurity describes a situation where there is visible shortage or unreliable access to foods that are safe and nutritionally sufficient (National Research Council 2006).

FAO (2014) reported that only 63 nations (out of a total of 136 nations and territories under its surveillance) have reached the hunger target of the Millennium Development Goals (MDGs) which were to be achieved at the end of 2015. The achievement was not in any way different at the end of the MDG target year. FAO (2015) posited that nearly all hungry people live in lower- and middle-income countries, while there exist eleven million people who are undernourished in developed countries. FAO (2017) reported that the highest prevalence (percentage) of undernourished people were in Africa, but, because Asia is the most populous region, it has the highest number of undernourished people globally. Hunger has multiple implications. For instance, hungry children may have social problems in school because they have higher rates of anxiety, aggression, and cognitive problems. Lack of sustained and affordable access to food in adults is strongly related with high rates of mental health problems, hypertension, diabetes, poor sleep, and overall poor health (Gunderson and Ziliak 2015). In addition, United Nations (2018) posited that hunger and malnutrition are the number one risk to health, more than malaria, AIDS, and tuberculosis combined.

Inequality is simply the measurement of unequal distribution of resources within a particular region or state. Inequality does exist in various forms, such as gender, social, and economic. The concept of inequality has been in existence for ages. In fact, inequality contributes to the workings of the society. Klasen (2009) posited that inequality has increased in many developing nations and SSA lags behind the two other developing regions of South Asia and the Latin America and the Caribbean (LAC) in nearly every measure of inequality—political,
socio-economic, or environmental. The situation is likely to worsen except serious efforts are made to reverse it. However, the situation has not led to the point where there is increase in the documented numbers of hunger-related deaths despite the fact that one in seven still suffer from chronic hunger (Mugambiwa and Tirivangasi 2017). Meanwhile, there are increases in major factors possibly contributing to hunger which include reduction of food production per capita; reduction in food imports compared with needs possibly due to reduced affordability; and high population growth rate which in many countries have outweighed carrying capacities among others.

Over the years, global population has continued to grow astronomically. The world is said to have a population of 7,594,270,356 people as at the end of 2018 (World Bank 2019). Between the period 1980 and 2000, the world population increased from 4.4 billion to 6.0 billion with the figure forecast to rise to 9.2 billion by 2050 (World Bank 2010). In Africa, Nigeria is the most populous country. Despite her progressive increase in population, there has been a decline in agricultural production as observed by FAO (2014) which posited that land reform is a sine qua non in the same manner improvement in farm production throughout the country will guarantee sufficient food production. The same situation can be observed across other countries in SSA, such as Cameroon, Chad, Kenya, Senegal, Namibia, and Angola. Due to increase in population, aggregate demand for food in the world by 2050 is projected to grow by 60%. (FAO 2015). There is therefore the tendency for the world’s population to outgrow the capacity to feed it, especially in the developing and least developed countries of SSA. This idea was first expressed by Malthus (1826), in his article “Principles of population growth.” Malthus observed that population was increasing at a geometric rate while resources were growing at arithmetic rate. He therefore posited that unless checked by a reduction in food supplies or some voluntary moral restraints in terms of birth control and postponement of marriages or through other phenomena such as war and diseases such as the recent novel corona virus (COVID-19) which kills in thousands there are tendencies that population will outstrip food supply. This phenomenon of food-population imbalance was later termed by modern economists as ‘Malthusian population trap’ (Todaro and Smith 2012).

Klasen (2009) posited that increasing inequality is a major issue to developing countries just as it is of serious concern in the OECD countries. These include the rapidly growing ones. Rise in inequality can substantially increase poverty, decrease welfare and finally impinge economic growth among others. Odusola et al. (2017) posited that the relationship between population and inequality still remain unclear in Africa. It was reported that at the bivariate level, a negative and significant relationship existed with income inequality across the population variables but same did not hold at the multivariate level. Meanwhile, Bolhuis and de Pleijt (2016) reported that economic inequality may actually fuel population growth, particularly in countries which do not have universal access to education and health care. This is more so because economic growth must indeed outweigh population growth so that average income does not fall for countries to escape poverty. High birth rates make it extremely difficult for countries to escape poverty in the long run. In the opinion of Piketty (2014), low birth rates are partially responsible for the present increase
in inequality. This is because greater inheritance occurs due to few number of children per couple thereby worsening income inequality. However, the premises for this may not be applicable to SSA as the region still has one of the highest fertility rates. Social, economic, and political inequalities have been said to be responsible for uneven distribution of malnutrition and hunger (Hossain 2017). Truthdig (2018) posited that increased inequality compounds not only poverty, which is obvious, but hunger. Increase population will *ceteris paribus* put pressure on the available food supply while inequality may deny some people the resources to enhance their access to food.

There are only a limited number of studies which focused on some components of inequality, population growth, and hunger in literature, but to the best of our knowledge, none has brought the three concepts together in a single study and especially, with clear focus on hunger, let alone in the SSA region. The present study sought to examine the effects of population and inequality on hunger is SSA. The study therefore aimed at bridging the perceived knowledge gap and advance the frontier of knowledge in this area which is basic to humanity. In light of the above, answers were sought to the following research questions—is there any relationship between population growth and hunger in SSA? And, does inequality affect hunger in the region? In order to provide answers to the questions, the study specifically sought to achieve some specific objectives which were to determine the effect of inequality on hunger in SSA; determine the relationship between population growth and hunger in SSA; and finally, to assess the effects of GDP per capita, female literacy, economic stability, and country-level aggregate food production index (control variables) on hunger in the region. The study covered 46 Sub-Saharan African countries (with the exception of South Sudan whose data were not complete) from 2007 to 2017. Findings from this study are expected to be useful for directional policies aimed at reducing hunger by governments in SSA. This may serve as a springboard for further development.

**Empirical literature review**

A number of empirical studies involving one or some combinations of population, inequality, and hunger in different countries and regions around the world have been carried out with diverse findings. Leonid (2002) assessed the issue of regional inequality and polarization in Russia. Household-level data were compiled from Russian Longitudinal Monitoring Survey (RLMS) from 1990 to 1999 which were analyzed with Gini coefficient and Generalized Entropy measures. It was reported that while polarization and inequality rose sharply from early to mid-1990s, it reversed toward the end of the decade. The paper concluded that the fact that regions were polarized was due to difference in the structures between the regions instead of political and geographic factors in Russia.

Klasen (2009) assessed the implication of inequality on poverty alleviation and development in emerging economies. The work was against the backdrop of a lot of focus on inequality and its consequences in OECD countries as it was a burning issue. The study which used descriptive statistics and qualitative analyzes focused
on a wider perspective of inequality and examined how inequality trends and its impact as it festered in other parts of the world. It centered on three emerging economies of Brazil, India, and China. A number of descriptive analyses were deployed to show the trends of inequality. It was discovered that inequality has been rising in China and India but declined significantly since mid-1990s in Brazil. A key finding is that increasing inequality is avoidable in emerging economies and government policies is capable of effecting significant reduction in inequality.

Fosu (2009) comparatively examined how inequality alters the effect of growth in income on changes in poverty rates in SSA and non-SSA using data of 86 countries from 1977 to 2004 which were analyzed with a random effect model. The study revealed in all the measures of poverty considered that initial inequality had strong negative influence on the effect of GDP growth on poverty reduction. The effects were nearly the same for the two groups. Therefore, there were noticeable differences in the response of effects of growth in income on poverty conditioned on the level of inequality. Meanwhile, elasticity of income growth was obviously less for SSA, which suggested that poverty reduction responded marginally to growth.

Elmes (2016) did an extensive exposition of the implication of inequality in economic terms and food insecurity on the tendency for erosion of capabilities in the USA. It was imperative because these have given rise to protests, social mobilization, consciousness and novelties, and improvement of rules so that everybody will have right of access to and consumption of healthy food. The paper posited that more sections of American residents have been more obese and food insecure as they eat foods which can be classified as unhealthy just to survive thereby suffering declining capabilities compared with others which impairs their ability to participate well in the functioning of their community. Besma (2016) examined inequality and the poor in Tunisia with data from 2005 to 2010 using Fuzzy set approach and concluded that inequality and poverty were inextricably linked because poverty is a relationship between poor people and the society in which they live.

Mberu and Ezeh (2017) conducted a study in SSA aimed at re-examining the typical relationship between population and growth of the economy and development. However, Zambia and Botswana were selected as case studies to show the effects of different population growth rates in order to mitigate hunger in its various forms. The study which adopted descriptive analyses showed how divergent demographic indicators (population growth, fertility rate, etc.) for Zambia and Botswana since the 1960s provided insight into their divergent economic drives over the same period. The growth rate of the Botswana economy is one of the highest in the world alongside its diversified economy thereby ranking it as the most stable and well-to-do country in Africa, a far cry from Zambia whose economy lacked the needed diversity, with high external debt and hunger.

War could be one of the socio-political factors determining malnutrition in SSA countries. Therefore, Uchendu (2018) sought to determine the impact of war on population, malnourishment, food security, corruption, and life expectancy in the war-torn SSA countries (WTSSA). A total of 14 countries in WTSSA were sampled and the data were analyzed with t test, Pearson’s correlation analyses, and multivariate regression. Results revealed that hunger significantly impacts on life expectancy of both male and female. The study advocated for adequate food supply in aiding the
eradication of malnutrition. In addition, good governance and respect for fundamental human right were advocated to prevent war in Sub-Saharan African countries.

In a study by Bonuedi et al. (2019), the effect of institutions and the growth effects of population on economies in SSA were examined with a panel dataset of 39 countries from 2002 to 2013 and analyzed with the system GMM estimator. Results showed that increase in working population size had no direct effect on growth, except through the presence of strong and high-quality institutions. The implication of the finding of the paper was that except institutions are strong, active population size has little or no effect on growth and this may result into low standards of living and possibly worsening hunger as population growth increases. It was opined that rule of law, political stability, and corruption are the needed aspects of institutions that matter most if at all any benefit is to be achieved from the high working age population. Unfortunately, most Sub-Saharan African countries perform woefully in these aspects. With the empirical literature reviewed so far, little has been done in determining the effect of inequality and population growth on hunger especially in SSA. More importantly, the analytical procedure adopted in this study (the GMM estimator) is hardly used in this area of study despite its appealing features to address the interwoven nature of the key variables.

In summary, the related past empirical works reviewed so far suggested that increasing inequality was avoidable in emerging economies and government policies is capable of achieving significant reduction in inequality. Meanwhile, the income growth elasticity was obviously less in SSA and poverty responded marginally to income growth. Inequality in economic terms and food insecurity have the tendency to erode capabilities and these have given rise to protests, social mobilization, consciousness and novelties, and improvement of rules so that everybody will have right of access to and consumption of healthy food in some other climes. Economic growth rates and diversification of the economy have reduced hunger in some countries while lack of diversification and high indebtedness have caused high degree of hunger in some other countries. Health status of the people may be affected by hunger and lack of adequate food supply. Working population size had no direct effect on growth, except when there are strong and high-quality institutions, absence of which low standards of living and worsening hunger may occur as population growth increases. The foregoing review summary have thrown up some important variables for the present study which include the main variables for the study (population growth and income inequality) alongside other equally important variables such per capita income and food production.

Theoretical background

Malthusian population theory

Thomas Malthus (1826), in his essay on the “principles of population growth, posited that man would always be faced with the basic problem that rapid increase in population creates for food production. In other words, the theory simply established a direct link between population dynamics and availability of food resources. It was
posited that human development was constrained by the negative effect of growth in population on food availability. The theory was built on the assumptions affinity for food and sexes which were viewed as basic requirements for the existence of man. In the opinion of Malthus, food production was growing slowly compared with human population which was growing in multiple folds. Hence, the need to check population growth was emphasized and this was classified into positive and preventive checks. Actions categorized as preventive check include intentional reduction in population growth, such as postponement of marriage and birth control, while positive checks include natural holds on the population through factors, such as disasters, war, and diseases, e.g., the endemic and the pandemic types the world are presently witnessing such as malaria, tuberculosis, HIV/AIDS, Ebola Virus, and the most recent novel corona virus disease (COVID-19) which kills in thousands.

**Applicability of the Malthusian theory to the present scenario**

Although, the Malthusian theory of population has been criticized in several dimensions. For instance, the increase in food production and supply has been more than arithmetic progression as thought, while the growth of population has not realistically followed any geometric pattern to the extent that population will increase by 100 percent with a quarter of a century as projected by Malthus. He also did not see beyond England and did not envisage the opening up of new areas, e.g., the USA, Australia, and Argentina where there are virgin land for farming and sources of cheap food supply. He did not also envisage breakthrough in medical sciences and technology which has improved longevity (health) and boost agricultural production, respectively, among others. Only a few countries in Africa such as Cape Verde and Mauritius have experienced a demographic transition through a decreased birth rate. Meanwhile, the prevailing situation in most part of the SSA region is somehow similar to that of England or Europe when Malthus propounded his theory of population.

Despite these weaknesses, the Malthusian theory contains some truth which makes it applicable to some other climes, although, may no more be applicable to England and some other Western European countries. However, Europe was able to take precautionary measures due to Malthus’ earlier warning. The theory seems to be much applicable to most developing and least developed countries in some parts of Asia, Latin America, and the Caribbean and SSA where in some instances population grows faster than food supply and there are deaths by starvation or some forms of severe hunger and malnutrition. Positive checks like floods, wars, droughts, earthquakes, and epidemics, such as cholera, malaria, tuberculosis, and HIV/AIDS pandemic, still occur in all the underdeveloped and developing countries. The African agricultural sector has not been able to feed the people as it is relatively unproductive because aside the unfertile soil middlemen take the bulk of the profit. This happen because the farmers who are mostly aged are not connected to the market.

Many countries such as Angola, Burundi, Democratic Republic of Congo, Mali, Uganda, and Somalia with high population growth have already experienced civil wars or are experiencing some forms of conflicts. The probabilities of new internal
conflicts and wars within such countries are high. The proportion of young people in the population of these countries are extremely high and are mostly unemployed which makes them prone to vices, such as violence, armed robbery, terrorism, and readily available instruments for war. Table 1 presents some facts about population growth and food production growth in some selected African countries. It is obvious that the rate food production is some instances still lags behind rate of population growth in SSA, e.g., Angola in 1985, Burundi in 2010, Nigeria in 2015, and Mozambique in 1985 and 2015.

Kuznet’s theory of inequality

The crux of the Kuznet’s (1955) theory is that at the beginning of economic growth, there is tendency for high level of inequality which will later get better with time. This was the rationale behind the inverted-U curve. A number of explanations have been offered for the foregoing phenomenon. The structure of the economy has been said to play a major role in the situation described. As asserted in the Lewis model, growth of the economy in the early stage may concentrate in the city industrial centers. In the said areas, productivity and wages are very high, but there are only few employment opportunities which result in the initial disparities. There is expectation that inequality will reduce as a level of average income is reached and democracy becomes more entrenched alongside growth of the industrial sector. This likely to occur with spontaneous rise of welfare state. The inverted “U” shape is a major assertion of Kuznet as inequality rises and decline with improvement in the economy. Inequality is measured by Gini coefficient.

Relevance of the Kuznets’ hypothesis to the study

The Kuznets’ hypothesis have been severally criticized and some of the points of its criticisms include (a) that the Kuznets’ study which gave birth to the said hypothesis was based on data from Latin American countries only which were at a stage of development which could be described as intermediate and because of reasons which were peculiar to them had very high level of inequality at that time, (b) scholars also raised doubt about the validity of the hypothesis for different regions, and (c) its validity over different period has also been doubted.

However, the industrialization of England followed the Kuznets’ hypothesis. According to Halton (2020), the Gini coefficient in England rose to 0.627 in 1871 from 0.400 in 1823 and it fell to 0.443 in 1901. Furthermore, almost at the same time Sweden, France and Germany followed a similar development pattern. However, Norway and the Netherlands experienced different patterns as they witnessed reduced inequality because they changed from agricultural-based economies to industrial ones just as latter witnessed by those of the East Asian countries of Taiwan, South Korea, and Japan which some scholars ascribed to some cultural quirks or peculiarities. The land reforms which was implemented in the 1940s to 1950s engendered equity in distribution in the East Asian economies, notwithstanding the delay in political reforms. Meanwhile,
Table 1  Food and population growth in some selected African countries

| Country     | 1960 Population ('000) | 1960 Food Production ('000) | 1985 Population ('000) | 1985 Food Production ('000) | 2010 Population ('000) | 2010 Food Production ('000) | 2015 Population ('000) | 2015 Food Production ('000) |
|-------------|-------------------------|----------------------------|------------------------|----------------------------|------------------------|----------------------------|------------------------|----------------------------|
| Angola      | 5455 (N.A)              | 534,345 (N.A)              | 9,962 (82.6%)          | 306,335 (42.7%)            | 23,356 (134.5%)        | 1,176,051 (283.9%)         | 30,809 (31.9%)          | 2,869,848 (144%)          |
| Burundi     | 2797 (N.A)              | 129,001 (N.A)              | 4751 (69.9%)           | 249,340 (93.3%)            | 8676 (82.6%)           | 295,033 (18.3%)            | 11,175 (28.8%)          | 407,263 (38%)             |
| Cote d’Ivoire | 3503 (N.A)           | 242,052 (N.A)              | 9918 (183.1%)          | 902,604 (272.8%)           | 20,532 (107%)          | 1,560,122 (728.5%)         | 25,069 (21.9%)          | 2,563,702 (66%)            |
| Nigeria     | 45,138 (N.A)            | 7,846,711 (N.A)            | 83,563 (85.1%)         | 11,412,810 (45.4%)         | 158,503 (90.4%)        | 23,160,948 (102.9%)        | 195,875 (23.6%)         | 23,948,771 (3.4%)          |
| Mozambique  | 7185 (N.A)              | 613,495 (N.A)              | 12,764 (77.6%)         | 717,362 (16.9%)            | 23,513 (84.2%)         | 2,716,826 (279%)           | 29,496 (17.4%)          | 1,872,518 (−31.1%)         |

Figures in brackets are percentage growth compared with selected previous values

The food production is total cereal production (in tons) in milled rice equivalent

Sources World Bank and FAO statistical Database
Kuznets concluded that there was still the need to do more in replicating such research in order to assert the relationship between inequality and economic development.

Kaelble and Thomas (1991) posited that only a fraction of the variations in income inequality was explained by Kuznets hypothesis. The obvious implication of this is that some other characteristics inherent in each country or region, such as political institutions, sociocultural settings, and economic structure, are important factors playing important roles in determining the level of inequality in any country. Despite the criticisms, the Kuznets’ hypothesis is still suitable for the economies of the Sub-Saharan Africa region which is highly agrarian and still remains one of the most unequal regions in the world.

Theories of Food Insecurity

The concern of the Neo-Malthusian perspectives regarding food security is mostly issues regarding the ability of the earth to produce enough food for the people without distorting the ecological balance. According to Scanlan (2003), if the world is able to meet the demand of the people without compromising those of future generation, then food security may be maintained. The Techno-ecology theory of Berry and Cline (1979) and Simon (1998) takes a more positive approach to food security. The theory believes that human ingenuity and technology are the most valuable assets and these are not in any way facing the problem of scarcity. This is very similar to believe of the Food Decline Approach (FDA) which believes that food supplies are the major cause of food security. This was the school of thought which drove the “Green Revolution” and the diffusion of technology to less Developed Countries (LDCs) where there are food shortages. The failure of FDA gave birth to the Amartya Sen (1981) Entitlement Approach to food security which posits that food insecurity was not because food was not available in the market but poverty or lack of purchasing power prevents people from being able to acquire food. The Dependency and World System Theory considers international factors in hunger. It considers each country in relation to the world food order. The Urbanization theory as relates to food insecurity/hunger posited that development is always in favor of urban areas because economic elites garner political powers in the cities and enact policies to the advantage of the urban areas while they leave rural areas underdeveloped. The differences between the rural and the urban areas are similar to the gaps between agricultural and industrial/manufacturing sectors of the economy. Example of this was given by Lipton (1977) in the concept of “price twisting.” Here, the State Commodity Boards gain by buying farm products at very low price and exporting them at international prices. Social stratification theory posits that inequality and stratification are important social considerations for food security. Food insecurity/hunger can be rooted in civil wars and other civil strives.
Methodology

Model specification

Thomas Malthus in his ‘Principles of population growth’ essay written in 1798 has profound implication and relevance to hunger which is the subject of the present study. One germane tenet of the theory posits that population growth will outpace agricultural production—that there will be too many people and not enough food (Malthus 1826). The FDA emphasized supply as a major factor to ensure security, hence, the inclusion of Food Production Index (FPI) in the model for the present study. The Entitlement Approach to Food Insecurity emphasized purchasing power and this was the basis for including per capita GDP (to proxy income) among the regressors in the study’s model. This is also in line with clues from the empirical literature. The Kuzet theory of inequality, the social stratification theory, and previous literature were the bases for the inclusion of inequality in the model. To this end, the model for the present study therefore conceived hunger as a function of inequality, population growth, income, food production index alongside other relevant explanatory variables as suggested in empirical literature, such as inflation rate (to reflect economic stability) and female literacy rate proxied by female primary school completion rate (as a social indicator). The empirical model is therefore specified as follows:

\[ HIN = f(INEQ, POP, FPI, GDPC, INF, FPCR), \]

where \( HIN \) is the Country’s Hunger Index, \( INEQ \) is the Inequality (measured by Gini coefficient), \( POP \) is the population, \( FPI \) is the Food Production Index, \( GDPC \) is the GDP per capita, \( INF \) = Inflation Rate, and \( FPCR \) = Female Primary School Completion Rate.

From Eq. 1, the econometric form of the model can be stated as follows:

\[ HIN_{it} = \alpha_0 + \alpha_1 INEQ_{it} + \alpha_2 POP_{it} + \alpha_3 FPI_{it} + \alpha_4 GDPC_{it} + \alpha_5 INF_{it} + \alpha_6 FPCR_{it} + \mu_{it}, \]

where “\( \mu \)” is the disturbance term and \( i \) is the country subscript, while \( t \) is the time subscripts. The \( \alpha_s \) represents the parameters of the explanatory variables.

Data sources and measurement

Data were collected on relevant variables from 46 SSA countries from 2007 to 2017. The description of the variables used are as follows:

Hunger Index (HIN)

The Global Hunger Index (GHI) is obtained by taking the mean of proportion of the population that do not have sufficient food, the proportion of underweight among under-5 children (Child Stunting and Child Wasting), and the proportion of under-5
mortality (Child Mortality). The resulting score is made on a 100-point scale, where a score of 100 reflects the worst situation, while zero represents ‘no hunger situation.’ The Global Hunger Index (GHI) was sourced from [www.globalhungerindex.org](http://www.globalhungerindex.org).

**Inequality (INEQ)**

This was proxied by the Gini coefficient score. The Gini coefficient may be obtained by ratio of the difference between the line of perfect equality (0.5 by definition) and the area below the Lorenz curve to the area below the line of perfect equality.

**GDP per capita (GDPC)**

This was obtained by dividing gross domestic product by mid-year population. GDP itself represents addition of value added by all the people living in the country, including product taxes while excluding subsidies. This was sourced from World Development Indicator (WDI). It was used to proxy income of individuals in the economies.

**Population (POP)**

This is measured by the number of people living within a specific geographical area in a year and was sourced from World Development Indicator (WDI).

**Food Production Index (FPI)**

This is measured by the total of food produced less amount needed for seeds and feeds. Each country’s index is obtained using Laspeyres formula where aggregate for the concerned year is divided by the average aggregate for 1979–1981 taken as the base period. FPI was sourced from Food and Agriculture Organization (FAO) at [www.fao.org](http://www.fao.org).

**Inflation Rate (INF)**

This is measured by the consumer price index and shows the percentage change in the cost of good basket of an average consumer using the Laspeyres formula (WDI 2020).

**Female Primary School Completion Rate (FPCR)**

In the present study, this was used to proxy Female Literacy Rate (FLR). FPCR is the number of new people in the last grade of primary education irrespective of age, divided by the population at the entrance age for the last grade of primary education (WDI, 2020).
Data analyses

Pre-estimation

The pre-estimation analyses consisted of descriptive and correlation analyses. The descriptive analyses were carried out to have proper understanding of the structure of the series. The correlation analysis guided against multicollinearity in the model that was estimated so that two explanatory variables which are highly correlated did not co-exist in the model in order to avoid multicollinearity.

Estimation

The study adopted the System GMM estimation procedure. The use of GMM in the study was based on three motivations. These included the fact that the number of countries was higher than the number of years. The study was based on a panel of 46 SSA countries covering a period of 11 year (2007–2017). The second motivation was that GMM is a dynamic panel estimator which controls for endogeneity and reverse causality since the study variables included inequality which may cause hunger and hunger may cause inequality. In the same vein, population may cause hunger and prolong hunger can result in deaths which may reduce population. Inequality may also affect female primary school completion rate and vice versa. These portend endogeneity problem, and in addition there is endogeneity problem regarding the lagged-dependent variable in a dynamic panel model (due to the existence of correlation between the regressors and the disturbance term) which is taken care of by GMM. Thirdly, the method takes care of unobserved panel heterogeneity, omitted variables bias, and measurement errors. The instrumentation process of the method allows for the employment of instruments to control for simultaneity or reverse causality which is very important in the present study.

Equations 3 and 4 which represent the level and the differenced form, respectively, give summary of the procedure for the system GMM estimation:

\begin{align*}
HIN_{it} &= \sigma_1 HIN_{i,t-1} + \sigma_2 \text{INEQ}_{i,t} + \sigma_3 \text{lnPOP}_{i,t} + \sigma_4 \text{lnFPI}_{i,t} \\
& + \sigma_5 \text{lnGDPC}_{i,t} + \sigma_6 \text{INF}_{i,t} + \sigma_7 \text{FLR}_{i,t} + \eta_i + \mu_t + \epsilon_{i,ji},
\end{align*}

(3)

where \(\eta\) is the country-specific effect, \(\mu\) is the time-specific effect, and \(\epsilon\) is the error term.

In order to do away with country-specific effect \(i \cdot \eta_i\), the first difference is taken of Eq. (3).
The dynamic system Generalized Methods of Moments (sGMM) has been shown to be most suitable for the estimation. Applying system GMM involves transforming the mathematical expression in Eq. 3 above to get rid of unobserved country effects and thereafter estimating the derived equation using instrumental variables approach. Arellano and Bond (1991) based on first differences actually worked out GMM estimator for the coefficients, adopting lagged levels of the explained variables and the predetermined variables (“internal instruments”) and also taking differences of the strictly exogenous explanatory variables. The assumption of this novel approach is that there is no second-order autocorrelation in the first-differenced idiosyncratic errors.

Post-estimation

The GMM tests for instruments validity and for autocorrelation of the error terms through the following:

**Hansen J test**

The Hansen J test was adopted to examine over-identifying restrictions in the model. This is a procedure necessary in testing for instruments validity. The null hypothesis is that the instruments as a group were exogenous. An acceptance of the null hypothesis implies that the right instruments have been chosen.

**Sargan test**

The Sargan test like the Hansen J test is also used to test over-identifying restrictions in the model. However, the Hansen–J test is often used to assess the validity of the instrumental variables. The null hypothesis of the Sargan test is that instruments have overall validity.

**Test for autocorrelation of the error term**

The system GMM estimation automatically examines the estimated model for the presence of serial correlation of the first order referred to as AR(1) test and that of
second order, AR(2) test, in the differenced error term series. The moment conditions are said to be correctly specified and no autocorrelation in the original disturbance term when the null hypothesis of the AR(1) test is rejected alongside the acceptance of the null hypothesis of AR(2) test. The Arellano–Bond tests for AR(1) and AR(2) were adopted to carry out these tests. There is however no cause for alarm if the null hypothesis of AR(2) (which is the absence of second-order autocorrelation) is not rejected.

**Results and discussion**

Pre-estimation: Analyses carried out here included the descriptive statistics and the correlation analyses of the study variables.

**Descriptive analyses of study variables**

The descriptive statistics show that the statistical characteristics of the data series employed in the estimation which assisted in defining the appropriate precautions to be taken during estimation. Table 2 below shows the descriptive statistics in a summarized fashion. The variables presented in the descriptive analyses are Hunger Index (HIN), Inequality (INEQ), Food Production Index (FPI), GDP per capita (GDPC), Population (POP), Inflation rate (INF), and Female Primary School Enrollment Rate (FPCR). Between 2007 and 2017, HIN, INEQ, FPI, GDPC, POP, INF, and FPCR averaged 22.2937, 0.5903, 123.2261, $1623.05, 19,694,741.67, 5.78%, and 54.17%, respectively. All the variables skewed to the right (positive values) and this suggested that most of the observed values lie to the left (low values), while the long tail lied to the right except for GDPC and FPCR which skewed to the left. In terms of kurtosis, HIN and FPI were mesokurtic (moderately peaked) in distribution, while INEQ, POP, and INF were leptokurtic (highly peaked or with pointed tails).

| VARIABLE  | HIN  | INEQ | FPI    | GDPC  | POP          | INF       | FPCR         |
|-----------|------|------|--------|-------|--------------|-----------|--------------|
| Mean      | 22.2937 | 0.5903 | 123.23 | 1623.05 | 19,694,741.67 | 5.7822 | 54.1693     |
| Median    | 21.735  | 0.5842 | 118.15 | 1657.36 | 10,988,222.5 | 5.6128 | 54.7063     |
| Maximum   | 50.9   | 0.8516 | 206.96 | 1695.97 | 190,873,311   | 17.4600 | 58.7967     |
| Minimum   | 3.830  | 0.4408 | 75.58  | 1496.56 | 85,033        | 3.5507  | 49.4586     |
| Std. Dev  | 8.6802 | 0.0597 | 23.74  | 66.0328 | 29,605,966.80 | 1.8967  | 3.3693      |
| Skewness  | 0.3099 | 2.3028 | 0.8773 | −0.6852 | −3.2767       | 1.1759  | −0.1452     |
| Kurtosis  | 2.9661 | 9.8538 | 3.4085 | 2.0974  | 15.8082       | 4.0720  | 1.5894      |
| Jarque–Bera | 7.03  | 1031.29 | 61.52  | 1.4586  | 4312.45       | 3.3402  | 1.0370      |
| Probability | 0.0297 | 0.1397 | 0.0043 | 0.4822  | 0.0002        | 0.1882  | 0.5954      |
| Observation | 552    | 552    | 552    | 552    | 552           | 552     | 552         |

*Source* Authors’ computation (2019)
top) in distribution and the remaining series (GDPC and FPCR) were platykurtic (flat top). However, for more comprehensive assessment of normality of the distribution of the series, the Jarque–Bera test which has been made more evolving by combining the properties of skewness and kurtosis was adopted. At 5% critical level, INEQ, GDPC, INF, and FPCR were normally distributed, while HIN, FPI, and POP were not.

**Correlation analysis**

Correlation is the magnitude of linear relationship between two or more variables. This analysis was carried out for the present study to prevent multicollinearity by avoiding the inclusion of two or more highly correlated variables in the estimated model. Table 3 shows the coefficients of various pairs of variables and there was no bivariate correlation high enough to be a source of concern for the incidence of multicollinearity in the estimated model.

| Variables | HIN | LNPOP | INEQ | InGDPC | FPI | INF | FPCR |
|-----------|-----|-------|------|--------|-----|-----|------|
| HIN       | 1.0000 |      |      |        |     |     |      |
| LNPOP     | 0.2385 | 1.0000 |      |        |     |     |      |
| INEQ      | −0.1338 | −0.1933 | 1.0000 |        |     |     |      |
| InGDPC    | −0.2835 | 0.7054 | 0.0542 | 1.0000 |     |     |      |
| FPI       | 0.1613 | 0.2674 | 0.0348 | 0.0910 | 1.0000 |     |      |
| INF       | 0.4072 | 0.3609 | 0.6138 | 0.2194 | 0.6903 | 1.0000 |      |
| FPCR      | 0.2139 | 0.0349 | −0.181 | 0.0914 | 0.0619 | 0.3201 | 1.0000 |

Source: Authors’ computation, 2019

Table 4 Two-step system GMM estimates

| Independent variables | Co-efficient | t-statistics | Probability value |
|-----------------------|--------------|--------------|------------------|
| HIN(−1) (lagged hunger) | 0.8701*** | 10.02 | 0.000 |
| INEQ                  | 0.3038**    | 1.98 | 0.049 |
| InPOP                 | 0.0810***   | 2.89 | 0.006 |
| InGDPC                | −0.0911***  | −2.62 | 0.009 |
| InFPI                 | −0.0012*    | −1.95 | 0.068 |
| INF                   | 0.4617      | 1.16 | 0.182 |
| FPCR                  | −0.1206     | 1.50 | 0.141 |

Source: Authors’ computation, 2019

F-stat: 87.55 p value (F-stat): 0.000 Dependent Variable = HIN
No. of instruments = 27, Number of groups = 46, Number of observations = 506
Year Dummies = Yes

***, **, * are statistical significance at 1%, 5%, and 10%, respectively
Result of system GMM estimation

In the system GMM results presented in Table 4, instrument was reduced with “collapse” option of STATA command. Also, log of GDPC was included as an endogenous variable since theoretically, current realizations of growth depends on its past values. This was why InGDPC was excluded from the list of exogenous instruments.

The result of the two-step system GMM estimation showed that five among the seven regressors significantly affected hunger in SSA. Lagged hunger index, inequality, and population returned positive coefficients, while economic growth and food production index returned negative coefficients in line with a priori expectations. The positive and significant coefficient of the lagged-dependent variable (at 1% level) may be a pointer to the persistent nature of hunger. An increase in the previous year hunger by 1% increased the present-year hunger by 0.8701% Ceteris paribus. A hungry man may not have the strength to work nor have the privilege of being positioned to be gainfully employed or utilize opportunities. Hence, he continues to wallow in a vicious circle of lack, and hunger persists in his day-to-day life. Inequality coefficient value of 0.3038 which was significant at 5% level means that a percent increase in the measure of inequality expectedly increased hunger by about 0.3%. This is in line with a report published some decades ago where Wade (1976) posited that if allowance is made for the uneven distribution of food between the rich and the poor about 75% (which amounts to about 1.03 Billion people) of the population of the underdeveloped countries at that time received diets which contain less than the recommended calories. The deficiency which was about 400 billion calories a day amounts to about 38 million tonnes of grain per year which was as at that time merely 4% of total yearly cereal production. The main problem as emphasized in the paper was the manner food was being distributed between the rich and the poor. This further underscored the damaging role inequality plays in promoting hunger in most countries and regions of the world. Inequality decreases access to food and access to resources needed to purchase food.

Population came up with positive and significant coefficient at 1% level. Results showed that a percent increase in population caused about 0.081% increase in the measure of hunger. This actually corroborates the fear expressed by Malthaus in his 1798 article despite the advent of improvement in approaches to agriculture which include mechanization, improved seedling, and post-harvest technologies. It might have come to pass that population is growing faster than the rate of food production. It is believed that when there is improvement in the economy via noticeable growth and development most people are likely to become prosperous enough to afford the cost of food and become food secured thereby averting hunger. Therefore, the significance and negative coefficient of GDPC in the present study corroborates expectations. A percent increase in income (GDPC) resulted in 0.08% decrease in hunger. This further underscores the need to ensure the growth of the economies of countries in SSA in order to significantly reduce hunger.

Supply is Ceteris paribus expected to reduce scarcity and possibly hunger; therefore, the negative and significant coefficient of food production index were in line with expectation. There is therefore the need to encourage massive production and value addition in the agricultural sector. The sector has been the major employer of
labor in developing countries (SSA countries inclusive) engaging over 50% of the populace. Therefore, policies aimed at improving activities in the sector is expected to have multiplier effect on unemployment, economic growth, and general well-being. Inflation whose main components are prices and wages changes did not significantly affect hunger in SSA. In the same vein, a social indicator female primary school completion rate (FPCR) was not significant.

Post-estimation analyses

Serial correlation test

GMM assesses the estimated model to ascertain whether or not there is autocorrelation is present. The test was carried out as explained under the methodology and the results are presented in Table 5. The first- and second-order autocorrelation tests AR(1) and AR(2) in this study have probability value of 0.0037 and 0.3620, respectively. These confirmed the presence of first order and the absence of second-order autocorrelation in the differenced error term as expected thereby establishing the validity of the model results in line with the assertion of Arellano and Bond (1991).

Sargan and Hansen tests

The above tests were adopted in order to confirm whether or not the instrumental variables used in the estimation of the GMM model were valid under the hypothesis that all the instruments used as a group were exogenous. These are necessary because the validity of the instruments determines the consistency of GMM estimates which is highly desirable. The Sargan and Hansen–J tests returned p-values of 0.1709 and 0.1581, respectively, thereby asserting the validity of the instruments (Table 6).

| Source | Authors’ computation, 2019 |
|---|---|
| **Table 5** Results of Arellano–Bond test of autocorrelation | **Z-statistics** | **p value** |
| AR(1) | −3.75 | 0.0037 |
| AR(2) | −0.68 | 0.3620 |

| Source | Authors’ computation, 2019 |
|---|---|
| **Table 6** Test for valid instruments | **Chi-square statistics** | **p value** |
| Sargen test | 13.62 | 0.1709 |
| Hansen test | 12.59 | 0.1581 |
OLS and Fixed Effect estimates are important for vital decision-making when carrying out the GMM estimation for dynamic panel models. It is expected that

Table 7  Summary OLS Result
Dependent Variable: HIN

| Independent Variables | Coefficients | t-Statistics | p value |
|-----------------------|--------------|--------------|---------|
| HIN_{t-1} (lagged hunger) | 0.9571*** | 23.61 | 0.0002 |
| INEQ | 0.1108 | 0.92 | 0.392 |
| InPOP | 0.0163 | 1.08 | 0.254 |
| InGDPC | -0.0101 | -0.91 | 0.361 |
| InFPI | -0.0011* | -1.86 | 0.073 |
| INF | 0.3823 | 1.51 | 0.139 |
| FPCR | -0.1304* | 1.94 | 0.078 |

Source: Authors’ computation, 2019

$R^2 = 0.9194 \quad F$-Stat = 303.71 \ Prob (F-stat) = 0.0000

*Significant at 10%, **significant at 5%, and ***significant at 1%

Table 8  Summary of Fixed Effect estimate result

| Independent Variables | Regression Coefficients | t values | p value |
|-----------------------|-------------------------|----------|---------|
| HIN_{t-1} (lagged hunger) | 0.5165*** | 8.51 | 0.000 |
| INEQ | 0.1204 | 0.29 | 0.791 |
| InPOP | -0.7904* | -1.95 | 0.054 |
| InGDPC | 0.0817 | 0.66 | 0.481 |
| FPI | -0.0012* | -1.93 | 0.062 |
| INF | 0.1772 | 1.05 | 0.375 |
| FPCR | 0.1102 | 1.32 | 0.196 |

Source: Authors’ computation, 2019

$R^2 = 0.6501 \quad F$-Stat = 41.82 \ Prob (F-stat) = 0.0000

*Significant at 10%, **significant at 5%, and ***significant at 1%

Table 9  Long-run GMM estimate

| Variables | Coefficients | P value |
|-----------|--------------|---------|
| InPOP | 0.5082** | 0.025 |
| InGDPC | -0.4911** | 0.048 |
| INEQ | 1.4309** | 0.021 |
| InFPI | -0.0049 | 0.318 |
| INF | 0.0881 | 0.402 |
| FPCR | -0.2105 | 0.137 |

Source: Authors’ computation, 2019

*Significant at 10%, **significant at 5%, and ***significant at 1%

**OLS and fixed effect estimates**

OLS and Fixed Effect estimates are important for vital decision-making when carrying out the GMM estimation for dynamic panel models. It is expected that
the lagged-dependent variable estimated coefficient of the GMM lies between the fixed effect and the pooled OLS estimates (Roodman 2009). From Table 7, it is clear that the lagged HIN coefficient value of 0.9571 was significant at 1%. All other variables except food production index and FPCR were not significant at all acceptable levels. Food production and FPCR expectedly reduced hunger significantly at 10% levels of significance.

From Table 8, the lagged HIN coefficient was 0.5165 and it was significant at 1% probability value. All other variables were not significant except InPOP (population) and InFPI (food production index) which were negative and significant at 10% level. This is different from the results from earlier estimates in the present study.

**Long-run GMM estimate**

Table 9 presents the result for the long-run GMM estimate. It was found that only real food production and inflation were not significant in the long run. This may be understandable as food production in the previous year may not last too long to avert hunger in subsequent years. This is more plausible in developing countries such as SSA where there is still infrastructure deficit which may not encourage effective storage and given the perishable nature of some of the food crops being produced in the region. In summary, population and inequality increased hunger in the long run, while per capita GDP reduced hunger in SSA.

**Robustness check of the two-step system GMM result**

There is the need to assess the robustness of GMM results and this involves comparing the coefficient of the lagged regressand in the system GMM with those obtained in the pooled OLS and fixed effect model. Bond (2002) posited that for the system GMM results to be valid, alongside other criteria, there is the need for the coefficient of the lagged regressand to lie between its pooled OLS estimate and the fixed effect estimate. This criterion was fulfilled in the present study. The coefficient of the lagged-dependent variable (hunger index) in the GMM model lies between its values in the pooled OLS (results presented in Table 7) and fixed effect estimates (results presented in Table 8), i.e., 0.5165 < 0.8701 < 0.9571. Therefore, the estimated GMM model is confirmed to be valid and robust.

**Summary and conclusion**

The major aim of this study was to assess the relationship between inequality, population, and hunger. Other control variables included were food production, per capita GDP, inflation rate, and female primary school completion rate. Relevant data were sourced from the World Development Indicator (WDI). Because the number of the cross-sections was more than the number of period and due to endogeneity problem among others, the data series were analyzed using the system GMM.
The GMM estimation revealed that lagged hunger index, inequality, population, income (per capita GDP), and food production significantly affected hunger. Population and inequality had significant positive effect (increased hunger), while per capita income and food production significantly reduced hunger in the short run. In the long run, population, inequality, and income significantly affected hunger, while food production, inflation rate, and female primary school completion rate (FPCR) were not significant. The non-significance of food production in the long run was linked to the state of lack of social infrastructures for preservation and the perishable nature of farm produce. Hence, effect of food production quickly fades out as past years outputs had less hunger mitigating effect in the subsequent years. It is worthy of note that inequality exerted more greatly on hunger more than other significant variables in Sub-Saharan Africa thereby emphasizing its importance in tackling hunger in the region. Due to the significance of population, inequality, and income it was concluded that population growth still constitute a major problem to the well-being (hunger) of the people in the region. Inequality arising from uneven distribution of the societal wealth is another established cause of hunger in SSA. In situations where enough foods are not produced in a country such as those in SSA, food may be imported from countries with comparative advantage if the country is rich enough to afford such. The comparatively low per capita income in the region could not however support massive food importation which is also dangerous to the economy.

It is recommended that policies which may reduce inequality such as well-designed labor market policies, wealth redistribution policies such as selective taxation, inclusive growth policies, formulation of policies that can boost consumer spending and investment in order to boost economic growth, social safety, and social security policies alongside policies aimed at encouraging female education be formulated and pursued. There should be further enlightenment on population control, while the existing populace are meaningfully engaged. Policies which would enhance production expansion and productivity in the agricultural sector such as mechanization, provision of social amenities, transportation, and program support for value addition should be pursued. The agricultural sector is capable of creating multiplier effects that will reduce hunger and inequality and simultaneously boost the economy and the standard of living of the people. As SSA is still home to high proportion of hungry people (occasioned by war, poor economic policies, and low mechanization) the foregoing recommendations are useful for policy makers in the region.

**Author contributions**  Author SOA conceptualized the research, wrote the introduction, and did part of the data analyses and interpretation. SOA also wrote the summary and conclusion. Author PAO wrote the literature review (empirical and theoretical) and did part of the discussion. Author COO downloaded the data and assisted in data sorting and collated the reference list.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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