Assessing the Contribution of Agricultural Productivity to Food Security levels in Sub-Saharan African countries[1]

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Productivity isn't everything, but in the long run it is almost everything-Paul Krugman (1994)

Abstract

The study investigates the effect of agricultural productivity on different food security measures in Sub-Saharan Africa (SSA). We identify food security indicators with per capita total food available in tonnes and per capita nutrient supply (e.g., calories and proteins), while agricultural–value-added per hectare and cereal production per hectare are taken as measures of agricultural productivity in the study. Using a panel data covering 41 countries from 1980-2009, we employ both the dynamic and linear models. The empirical results from both models show that an increase in agricultural productivity contributes positively and significantly to all measures of food security considered in the study. Thus suggesting that the key to improving food security is by boosting the current level of agricultural productivity growth in SSA. Accordingly, we contend that policies geared toward increasing government investment in agricultural research and development (R&D) would likely raise agricultural productivity and subsequently food security levels in the region.

Key words: agricultural productivity, food security, cross-country, sub-Saharan Africa

JEL classifications: C01, C23, O11, O13, O4, O55

1. Introduction

Food and by extension nutrient intakes has been found to have a strong empirical linkage with human health and labour productivity (Aromolaran, 2004) because food insecurity is highly correlated with the risk of infectious diseases and malnutrition (WHO, 2015). Despite persistent global efforts towards alleviating food-poverty through various agricultural initiatives and interventions, food insecurity continues to be a major developmental challenge for a significant portion of the population in sub-Saharan Africa-SSA (World Bank, 2007).

The concept of food security has been defined in numerous ways and it has evolved considerably over the years. Many analysts and practitioners in this area define food security as a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2008). In terms of measurement, this definition reinforces the multidimensionality of food security by accounting for the following important factors: food availability (domestic food production and imports), food accessibility, food stability (food supply throughout the year), and food utilization (diet quality that meet needs for macro and micronutrients).

Food availability, which refers to per capita dietary supply, is one of the key variables for measuring society-well-being across the globe (Alexandratus and Braisnma, 2012). According to FAO (2015), per capita food supply is a widely used indicator for explaining global food security situation. This shows why food policy debate at macro-level (i.e., national/regional level) focuses on the per capita food available and per capita nutrient supply (Wang and Taniguchi, 2002). Available statistics show that dietary energy supply in Africa has increased by 25% from 2000 kcal to 2500 kcal per capita per day between the 1980s and the 2000s (FAO 2013). Similarly, availability of protein intake rose by about 11% from around 45g per capita per day to around 50g per capita per day during the same period. FAO (2015) also note that the prevalence of under-nourishment in Africa has decreased from about 28% to 20% between 1992 and 2014. Although Africa has recorded some progress, the average per capita total food available remains below the desirable levels for large part of the population in the region, especially sub-Saharan Africa. For example, average food available per capita in calories (kcal/person/day) and protein (g/person/day) over the years in SSA remains below the developing country average of 2500 kcal/person/day and 72g/person/day, respectively (Schaffnit-chatterjee, 2014; Ogundari and Ito 2015). This probably points to why the region still experiences very little progress in reducing food insecurity as nutritional quality of local diets remains low for most people and access to adequate food is not always certain for the poor in the region.

Agriculture plays a crucial role in economic development of many developing countries, especially SSA countries where the sector is large both in terms of employment and aggregate income. For example, agriculture is a major source of employment and income in sub-Saharan

Africa (SSA), accounting for 65% of employment and 32% of Gross Domestic Product-GDP (CTA, 2012). But given recent surge in global commodity prices, agriculture has again been in headlines because high food prices are increasing food insecurity and poverty in the developing countries. Accordingly, increase in agricultural productivity has been identified to stimulate greater food output, which could result in lower food prices and greater food availability in SSA (Fuglie and Rada, 2013), as higher agricultural productivity could also boost household and national income through increased trade and improved access to food (Rada et al., 2013, Awokuse and Xie, 2015). Also, there is increasing number of empirical evidence on the poverty reduction effects of agricultural productivity growth in the developing countries (Mellor, 1999; Thirtle et al., 2003, 2002, & 2001; Thirtle and Piesse 2007; Byerlee et al., 2009; Fan et al., 1999; Datt and Ravailion, 1998; Irz et al., 2001; Devkota and Upadhyay, 2013; Dzanku 2015).

Historical data on agricultural productivity growth from SSA reveals a relatively low estimate of about 2% per annum since the 1990s. While this could be considered an improvement on the negative growth rate during the 1960s and the 1970s, it is inadequate because average crop yield in SSA is still about 50 percent less than the average for developing countries (Rosen et al., 2014). For example, as of 2014, maize yield in SSA is about 20% of potential yield (Rosen et al., 2014), as Fuglie and Rada (2013) showed that despite recent recovery, agricultural productivity growth continues to lag behind other developing region of the world such as South Asia and Latin America in the region. In this context, Alene (2010) and Yu and Nin-Pratt (2011) identified decline in efficiency level as a major cause of the slow productivity growth in African agriculture. These studies found also that technical change is associated with adoption of improve technology and is likely to be one of the drivers of agricultural productivity growth in the region. Supporting this view, Fuglie and Rada (2013) note that the relative growth in agricultural productivity since 1990s in SSA can be attributed to investments in agricultural research, wider adoption of new technology and policy reform that have strengthened economic incentives to farmer in the region.

Agricultural productivity has always been measured in two ways in the literature, namely agricultural partial productivity and agricultural total factor productivity-TFP (Block 2010). While agricultural partial productivity refers to total agricultural output per unit of inputs used (e.g., total output per hectare or worker such as farm yield), agricultural total factor productivity (TFP) is defined as the ratio of the total agricultural output to aggregate contribution of all inputs used (Mainuddin and Kirby, 2009). Of these two measures, agricultural partial productivity is relatively easy to compute and because of this, it is widely used by economists and non-economists alike (Baker et al., 2003). Many previous studies examining the impact of agricultural productivity on poverty level highlighted above employed the partial measure of agricultural productivity such as agricultural-value-added per hectare or yield (e.g., Thirtle et al., 2003, 2002 &2001; Thirtle and Piesse 2007; Datt and Ravailion, 1998; Irz et al., 2001; Dzanku 2015). Likewise, we employ agricultural-value added per hectare and cereal production per hectare as agricultural productivity to ease the comparison of our finding with these studies.

The strategic importance of agriculture as a source of food has brought into focus the effect of agricultural productivity on food security levels in SSA. Likewise, the prevalence of global food insecurity has created interest in the role played by agricultural productivity in influencing food security in the region. This is because agricultural productivity taken as a proxy for domestic production capacity is viewed as one of the key factors necessary to improve food security in sub-Saharan Africa (Ogundari, 2014; Brümmer, 2006). Unfortunately, very little quantitative evidence exists on the impact of agricultural productivity on food security levels in the region.

To the best of our knowledge, there is no study that has examined the quantitative impact of agricultural productivity on food security in SSA. Hence, the present study attempts to fill the gap in the literature. The emphasis on agricultural productivity is further justified because not many countries have successfully achieved reduction in food insecurity without first increasing their level of agricultural productivity (Postnote, 2006).[2] To complement the potential effect of agricultural productivity, we also include a number of macro-economic factors as control variables that likely to influence food security levels in the region, as suggested by the previous studies.

The rest of the paper is organized as follows: The next section provides a brief overview of literature on food security indicators and determinants. Section 3 provides a detailed description of variables and data sources while section 4 presents the theoretical framework and empirical model specifications. Section 5 describes the results and section 6 contains the concluding remarks.

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[2] Agricultural productivity growth is required for industrialization to take place and the empirical investigations show that agricultural growth is causally prior to growth in manufacturing and services, but the reverse is not true (Thirtle et al., 2001)

2. A brief overview of literature on food security: indicators and the determinants

Food security is a complex concept whose definition has become multidimensional over the years. As a result, studies have looked at various factors that could influence food security. Such factors include political reform (Pieters et al., 2014; Smith and Haddad, 2015), economic growth (Heltberg, 2009), education, health, and human capital (Headey, 2012), and reduced conflicts (Jeanty and Hitzhusen, 2006). Given the importance of agricultural outcomes for the livelihoods of many living in SSA, deficit in domestic food production in SSA countries remains widely believed to be the bane of food security in the region. World Bank (2007) reveals that the failure to realize the potential of SSA agriculture has significantly compromised agriculture's role in reducing poverty and achieving food security. The study also presents agricultural productivity as a viable pathway for the region's achievement of food security. Nyairo et al. (2009), Ogundari (2014), and Schaffnit-chatterjee (2014) have also reiterated the importance of agricultural productivity growth for the SSA region. Although using micro data, Diao et al., (2012) showed that an SSA agricultural led economic growth will produce a decline in poverty that is 4 times higher than what non-agricultural led growth could produce - a positive empirical fact for efforts to make SSA food secure as food insecurity is closely linked to poverty level

An over view of the literature shows that studies that have looked at the impact of agricultural productivity on food security include Baldos and Hertel, (2014), African Human Report (2012), Rada et al., (2013) and Mainuddin and Kirby (2009). These studies employed either qualitative approach or simulation processes based on computable general equilibrium models, as rigorous econometric examination on the effect of agricultural productivity on food security in SSA is yet to exist. We aim to empirically quantify the effect of agricultural productivity on measures of food security so as to complement earlier quantitative works on the effect of agricultural productivity on poverty level based on macro data in SSA by Irz et al., (2001), Thirtle and Piesse (2007) and Thirtle et al. (2002 & 2003).

In the present study, we make use of per capita total food available in tonnes and per capita nutrient supply (e.g., calories and proteins) in each SSA country as indicators of food security in the study. Indicators used in previous studies include malnutrition and stunting (Smith et al., 2000; Smith and Haddad, 2015; Heltberg 2009; Headey, 2013); food production index, and under-five mortality rate (Wang, 2005; Pieters et al., 2014); self-sufficiency ratio in cereal consumption (Lee et al., 2016), and percentage of population that is undernourished (Sassi 2015). Our choice of per capita total food available and per capita nutrient supply seem to be plausible proxies for food security based on the following factors. **First,** since our main research interest is the effect of agricultural productivity on food security, we believe indicators that defined national food supply is arguably the best measures to provide evidence of direct relationship between agricultural productivity and food security. **Second**, the use of food availability rather than other dimensions of food security earlier mentioned in the study, is further justified by the fact that agricultural productivity affects food availability/supply directly through increased agricultural production. **Third,** we believe that if food is unavailable in the first instance, food can be neither accessed nor nutrients supplied to the body (Aker and Lemtouni, 1999). **Fourth,** the renewed emphasis on food availability also meant that there is consensus that hunger has its roots in causes related to domestic food production (Sassi 2015), which we believe has a strong link with agricultural productivity as a driver. Accordingly, we define food availability in the study following FAO (2013), as the total food supply in a country, which include domestic food produced, quantity of food imported, and changes in food stock (increase or decrease), less quantity of food exported, food used as planting material or as animal feeds, and damage to food produce during storage or transportation.

3. Source of data and data description

We made use of 1980 - 2009 balanced panel data set covering 41 SSA countries for our empirical analysis.[3] We construct the data set with data obtained on per capita nutrient available (such as calories and proteins), per capita total food available/supply in tons, agricultural-value added (also known as net value of agricultural production) based on the 2004-2006 international dollars, and total land for agriculture in hectare were obtained from the FAOSTAT database (FAO, 2013). Also, data on cereal yield or cereal production per hectare, life expectancy at birth, proportion of population less than 15 years old, proportion of population more than 64 years of age, proportion of urban population, and proportion of female population were taken from the

[3] The countries are Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape verde, Central Africa Republic, Chad, Comoros, Congo, Cote d 'Ivoire, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, South Africa, Swaziland, Tanzania, Togo, Ugandan, Zambia, and Zimbabwe.

World Bank's World Development Indicator database (WDI 2013). Likewise, data on trade openness and on real per capita GDP adjusted for purchasing power parity in 2005 US dollars were taken from the Penn World Table database (PWT 2013), as data on democratic status from Freedom House.[4]

We control for the macroeconomic variables such as real per capita GDP growth as explanatory variables in the empirical model because it measures over time, the purchasing power of the average citizen in each of the SSA countries for food purchases. We further control for factors such as good governance, demographic structure (proportion of dependent population), and trade openness that have been considered to affect food security, by including appropriate proxies for them in our analysis. For example, since good governance or political stability is essential to carry out programs that are conducive for the economic stability of households and the functioning of markets for essential nutrition inputs such as food (Smith and Haddad, 2015), we include political right index to control for the effect of good governance on food security levels in the study. We also include demographic structure because high number of dependents in a country can increase its food insecurity level. Trade openness is included in order to control for the impact of globalization on SSA's food security levels under the assumption that food imports (exports) occur if domestic supply is less (greater) than demand.

While detailed description, mean and standard deviation of the variables are presented in Table 1, it is important to mention here that we consider two indicators of food security. These indicators include per capita food available in tons/person and per capita nutrient supply (i.e., calories and protein intake). The study also include two measures of partial productivity represented by agricultural value added per hectare following the work of Thirtle et al., (2003), Thirtle and Piesse (2007), and Irz *et al.,* (2001) and cereal production per hectare. The inclusion of yield from cereal production is based on the fact that cereal provides two-third of total dietary energy (calories) available in the region.

<------------TABLE 1 HERE ---------->

[4] This variable has a scale from 1-7 with lower values indicating higher democratic freedom.

4 Theoretical Framework and Empirical model

4.1 *Theoretical Framework*

The theoretical framework for modeling determinants of food security at macro level has always been built within the hypothesis that variation in utility $U_f(.)$ arising from national food supply can be explained by variables representing macro-economic factors defined by m_i following the work of Reutlinger and Selowsky (1976), Colman and Nixon (1994) and Dawson (1997). Given the objective of the present study, we hypothesized that global food utility $U_f(.)$ can be defined as:

$$U_f = u_f\left(FSI \middle| m : AP, Z\right) \quad 1$$

where, FSI represents indicators of food security under consideration (i.e. per capita total food available in tonnes and per capita nutrient supply (e.g., calories and protein); m_i is a vector of determinants of FSI, which we hypothesized to include agricultural productivity AP and a number of macro-economic variables represented by Z in the study. Theoretically speaking, the empirical specification of the equation 1 has always been based on the reduced form described as:

$$FSI_i = f\left(AP, Z; \varepsilon\right) \quad 2$$

where, FSI and AP are as defined earlier; f represents functional form and ε refers to the error.

4.2 *Empirical Model Specification*

4.2.1. Dynamic Model

We employ a dynamic regression estimator in cognizance of recent evidence of persistency in the flow of global food supply (Kuhlgatz and Abdulai, 2012).[5] Evidence of persistence in global food supply is an indication that previous food supply represented by FSI_{it-1} determines its current supply represented by FSI_{it} . The implication of this is that, the food security indicator FSI_{it} and its determinants likely to follow a typical dynamic model specification in the study.

[5] Both Shen and Yao (2008) and Belke and Wernet (2015) also justify the use of dynamic model specification in their study based on the persistence of the distribution of income and growth of per capita GDP, respectively over time.

Given this, the dynamic model specification employed to address the objective of the study is written as:

$$FSI_{it} = \alpha + \psi FSI_{it-1} + \delta AP_{it} + \sum_{k=1}^{K} \beta_k Z_{ikt} + \mu_i + \tau_t + \varepsilon_{it} \qquad 3$$

where FSI_{it} is a vector of food security measures/indicators consider in the study, which include per capita total food available, FA_{it} and per capita nutrient available (i.e., Calorie and Proteins), NT_{it}, FSI_{it} are expressed in logarithm for the ith country at time t;[6] AP_{it} is a vector of agricultural productivity, which include agricultural value added per hectare and cereal production per hectare. Z_{it} is the vector of control variables hypothesized to also explain FSI_{it} and k is the number of control variables (Z) included in the model; δ is the coefficient of main interest, reflecting agricultural productivity effect on FSI_{it} while ψ_i and β_{ik} are parameters to be estimated . μ_i and τ_t are the country and time specific effects, respectively and ε_{it} is the idiosyncratic shock assumed to be independently distributed across the countries with zero mean and constant variance. Unlike FSI and AP, none of the Z variables are transformed into logarithm.

The use of ordinary least squares (OLS) as estimator for equation 3 is argued by Nickell (1981) and Baltagi (2008) to give biased estimates, as the estimation technique can barely correct for the inherent endogenity arising from the possible correlation between the lagged dependent variables FSI_{it-1} and the respective error terms ε_{it}. We thus make use of the generalized method of moment (GMM), which unlike OLS, assumes normality to correct for the inherent endogeneity and heteroskedasticity as well (Jaunky, 2013).

Specifically, we make use of the system-generalized method of moments (GMM) estimator proposed by Blundell and Bond (1998). The method involves the use of a linear combination of the lagged levels and differences of the variables as instruments. The system-GMM makes an exogeneity assumption where any correlation between endogenous variables

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[6] Further definition is as follows $FSI_{it} = \left[FA_{it}, NT_{it} \right]'$; NT_{it} is a vector of per capita calories C_{it} and per capita protein P_{it} supply: $NT_{it} = \left[C_{it}, P_{it} \right]'$

and unobserved fixed effects are constant over time, allowing the inclusion of level equations in the system and the use of lagged differences as instruments for the levels (Jaunky, 2013).

4.2.2. Linear Model

Many previous studies investigating determinants of food security at macro level (e.g., Smith et al., 2000; Smith ad Haddad 2000; Applanaidu et al., 2014 etc.) employs a linear model to investigate the determinants of food security. In an attempt to provide estimate that is similar to the previous studies in terms of specification, we re-specified equation 2 using a linear model shown below:

$$FSI_{it} = \alpha + \delta AP_{it-1} + \sum_{k=1}^{K} \beta_k Z_{ikt-1} + \mu_i + \tau_t + \varepsilon_{it} \qquad 4$$

where FSI, AP, Z_{ik} , δ_i, β_{ik} , k, μ_i, τ_t, and ε_{it} are as defined earlier. It is important to note also that we transformed FSI and AP into logarithm, while none of the variables represented by Z on the right hand side were expressed in logarithm.

Given that various types of shocks such as adverse weather conditions are probably persistent over time in the context of agricultural productivity analysis, (Vollrath, 2007) suggests possibility of serial correlation in the error term of equation 4 (Wooldridge 2007) which is likely to underestimate the standard error of the equation (Beck and Katz, 1995). Accordingly, we correct for possible serial correlation in equation 4 by following the work of Reimers and Klasen (2012) and Ball et al., (2013), as these studies employ Feasible Generalized Least Square (FGLS) model. According to Baltagi (2008), FGLS is robust to autocorrelation and cross-sectional contemporaneous correlation, which are critical concern in time series cross-section data used in the present study. Conversely, we provide estimate for FGLS two way fixed effect model in the analysis.

In the meantime, an issue of concern in both the dynamic and linear models is the possibility of endogeneity of the measure of agricultural productivity in the study. But a major challenge is obtaining valid instrument given that pure exogenous instruments that vary across countries and over time are rarely found (Farhadi et al., 2015). Hence, the use of ordinary instrumental variable (IV) regression estimators may not adequately address the endogeneity bias in equations 3 and 4. However, the advantage of GMM estimator for a dynamic is that, the methodology has the potential to control for endogeneity of all the explanatory variables by using internal instruments (Farhadi et al., 2015). According to Hauk and Wacziarg (2009), system GMM estimator can account for the reverse causality by producing valid instruments under the assumption that current period shocks in the error term do not affect past values of the regressors and the past values of the regressors do not directly affect current values of the dependent variables. As for the linear specification, we follow the suggestion of Thirtle et al., (2003) and Bhattacharyya and Hodler (2014) to use the lagged /initial values of the measure of agricultural productivity (AP) and other endogenous variables on the right hand side of equation 4. This approach has always been used to address the concern of endogeneity problem in the panel data (see; Thirtle et al., 2003; Bhattacharyya and Hodler 2014). To this end, we lagged the AP and Z endogenous variables on the right hand side of equation 4.

5.0 **Results and discussions**

5.1. *Diagnostic checks for the of dynamic specification*

The diagnostic check for the dynamic GMM model has always been based in the presence of first-order auto correlation-AR [1] and the absence of second–order auto correlation-AR [2] in the residuals of the model, and on the result of the Sargan/Hansen test of the over identifying restrictions tests for instrument validity (Yu *et al.,* 2011). Therefore, we present in the lower panel of Table 2, the reported AR [1], AR [2], and the Sargan test from the estimated dynamic-system GMM model for the study. Given the p-value, AR [1] is significantly different from zero, thus suggesting that first order serial correlation is probable in the data but this outcome did not affect the consistency of the result. As for the second-AR [2] order autocorrelation, we find that there is no serial correlation in the disturbances to this effect. However, the result of the Sargan test shows the validity of the instruments used in GMM model given the p-values reported, which thus suggest that the instruments are jointly exogenous.

5.2 *Effect of Agricultural Productivity on Food Security Levels*

The empirical results from both the dynamic and linear models are presented in Tables 2 and 3, respectively. Since our main explanatory variable of interest is the effect of agricultural productivity on food security levels, Tables 2-3 shows that irrespective of the choice of food security indicator considered, agricultural productivity which is proxied by agricultural value added per hectare and cereal production per hectare have a positive impact on the level of food security in the study area.[7] These results suggest that improvement in SSA agricultural productivity is a crucial factor in alleviating the problem of food insecurity in the region. Although, the finding is not new given the fact that the impact of agricultural productivity has long been projected with increasing effect on food security levels in the economic literature. Nevertheless, we believe, the present finding provides empirical evidence to back this argument in the literature, as lack of sustained agricultural productivity might aggravate the disappointing record of food security situation in SSA.[8]

However, a closer look at the literature reveals that the finding aligns with argument by Fuglie and Rada (2012) that a key factor to improve food insecurity is through robust and sustained agricultural productivity growth in the region. In addition, since food security and poverty are synonymous, we believe the finding in the present study aligns strongly with the previous studies on the impact of agricultural productivity on poverty level in SSA by Irz et al., (2001), Thirtle et al., (2002 & 2003) among others. The authors using similar measure of agricultural productivity as used in the present study found evidence that agricultural productivity significantly reduces the level of poverty (defined by head count ratio) in the region. Supporting this view also, Schneider and Gugerty (2011) note that positive impact of agricultural productivity on food security level is an indication that agricultural productivity can reduce food poverty in many ways, which include via price effect, increase in real income and decrease in poverty multiplier effect. Lee *et al.,* (2016) using macro data found evidence that agricultural productivity represented by cereal production yield significantly increase food security in the study. Recent evidence from micro studies like that of Minten and Barrette (2008) provides evidence that increase in rice yield has a strong positive effect on household food security level because doubling rice yield lowered the number of food insecure households in Madagascar.

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7 We also used agricultural total factor productivity (TFP) growth indices available on the United State Department of Agriculture (USDA) website and discussed into detail in Fuglie and Rada (2013) as a proxy for agricultural productivity in the study. The major challenge here is the counter intuitive nature of the result obtained. We find that agricultural TFP has a significant negative effect on food security level, which makes it difficult to drive home any policy conclusions. Conversantly, we stick to the partial productivity measures used since it provides level ground to compare our finding with previous studies either at micro and macro level given that these studies also employ partial productivity measures. For brevity, we did not present the result but it could be obtained from the authors if requested.

8 We also extend the dynamic model presented in Table 2 to include two lags of the dependent variables. We find that the result is very similar to the one presented in the study. For brevity, this is not presented but could be requested from the authors.

Likewise, Dzanku (2015) using micro level data found evidence that agricultural productivity defined by production yield decreases poverty and increases food consumption in Ghana.

Although the result of the study undeniably supports the role of improved agricultural productivity on reducing food insecurity, there has been the debate surrounding the quality of data from the two leading economies from the region, namely South Africa and Nigeria, which could cast doubt on the results. For example, arable land and permanent cropland data from the FAO database used to compute the net value of agricultural production yield for Nigeria in the study is likely to overestimate the contribution of agricultural productivity (Fuglie and Rada, 2013). The authors further state that the structure of agriculture is primarily composed of large commercial farms in South Africa, which differ from the rest of the region. This observation could undermine the value of both the net-value of agricultural production yield and cereal yield taken as a proxy for agricultural productivity in the study. We subsequently remove these two countries from our database and re-estimate the models. The empirical results still show that agricultural productivity is found to have positive and significant correlation with all measures of food security considered in this study. This result is not presented for brevity but it could be requested from the authors.

However, an issue of concern is the link between agricultural productivity and household welfare (e.g., food security), which is not as obvious as one might suppose (Dzanku 2015), as it has both direct and indirect effect. For example, Schneider and Gugerty (2011) revealed that positive effect of agricultural productivity on food security could lead to lower food price, increase in real income and decrease in poverty multiplier effect. Also, positive agricultural productivity-food security nexus could enhance smallholder farmers' opportunity to produce more at the same level of resources, which in turn lead to increase in their food security and income levels (Rada et al., 2013). As also noted by Gallup et al., (1997), increase in the agricultural productivity growth is likely to enhance smallholder farmers opportunity to produce more, which in turn could lead to increase in their food security and income levels. The overall implication is that efforts to increase agricultural productivity (such as intervention aimed at adoption of agricultural technology) may go beyond food security level, as it is likely to affect farm income and rural development in general.

But sustained agricultural productivity growth has remained a significant challenge in SSA's agricultural sector in contrast to other developing regions of the world such as Latin

American and South Asia (Fuglie and Rada 2013). Another source of concern is that area expansion rather than yield increase has become important driver of grain productivity growth in SSA, given that higher yield is expected to be a response to better seeds (technology) and improved farming technique in the region (Rosen et al., 2014; Udry 2010). Also, evidence of decline in technical efficiency levels as a major cause of poor productivity growth of African agriculture has also been reported in the literature (Alene 2010; Yu and Nin-Pratt 2011; Ogundari 2014). In addition, lower productivity of African agriculture may be due to policy neglect (Timmer 2005),

Since literature have shown that food security cannot be divorced from agricultural productivity in SSA (Ogundari 2014), as improvement in agricultural productivity needs to be explored to effectively address food insecurity problem in developing economies (Brümmer, 2006). Recognizing this, we argue that for agriculture to make a sustained contribution to food insecurity and hence poverty in SSA, productivity of agricultural sector must improve significantly in the region. But an important concern is the identification of policy measures that could be directed towards this in the region (Alene 2010; Yu and Nin-Pratt 2011). Fuglie and Rada (2013) argue that the policy measures might start with dissemination of new agricultural technologies and practices to the farmers in the region. The authors argue further that interventions aimed at improving agricultural productivity; in particular investment in agricultural research (R&D) and adoption of agricultural technology would likely raise agricultural productivity and subsequently food security levels in SSA. Also, several studies have argued that agricultural R&D plays an important role in improving agricultural productivity by generating more output from the same amount of input with ultimate aim of increasing the supply of domestic food production (Pardey et al., 2006; De Janvry and Sadoulet, 2010). For example, Comprehensive Africa Agriculture Development Program (CAADP) established in 2003 is aimed at reducing poverty and attained food security via agricultural-led poverty reduction strategy that is based on agricultural productivity revolution in the region. [9] A similar effort is also pursue by the Consultative Group on International Agriculture Research (CGIAR) centers to reduce poverty, hunger and malnutrition by sustainably increasing agricultural productivity in the region and developing countries in general (Fuglie and Rada, 2013).[10] This

[9] CAADP is an initiative established in 2003 by the Africa Union's New Partnership for Africa Development (NEPARD).
[10] Interestingly, many of the new technologies adopted in SSA are attributed to research conducted by the CGIAR centers across the globe.

observation aligns with the argument in the literature on why national and international development policy efforts to reduce food insecurity and poverty hinges on agriculture productivity-led poverty reduction strategy in SSA countries.

<------------TABLES 2 & 3 HERE ---------->

6. **Concluding remarks**

The study investigates the effect of agricultural productivity on different indicators of food security in sub Saharan Africa (SSA) using balanced panel data on 41 SSA countries covering 1980-2009. It made use of both the dynamic and linear models for the empirical analysis. Per capita total food available/supply in tonnes and per capita nutrient supply (e.g., calories and proteins) are two indicators of food security employed in this study while agricultural value-added per hectare and cereal production per hectare represent proxies for agricultural productivity. In addition, we also include trade openness, GDP per capita growth, democracy index, and demographic structure as other predictors of the level of food security.

Given the goal of this study, we are interested in the effect of agricultural productivity on the level of food security. Empirical results from both the dynamic and linear models show that agricultural productivity does have a significant positive effect on all food security measures considered in the study. This finding suggests that improvement in the agricultural productivity is crucial to attainment of higher level of food security in SSA. Steps toward meeting the challenge of increasing food demand would require increase in smallholder agricultural productivity in the region.

Since higher productivity rates are reflective of new technologies, long term investments in agricultural technologies and the adoption of modern agricultural practices and management techniques are central to raising agricultural productivity and subsequently food security levels in the SSA region. Governments of SSA countries should therefore channel resources into agricultural research and on ensure that research outputs are appropriately disseminated to smallholder farmers in order to raise agricultural productivity and subsequently food security levels in the region. This is based on the assumption that sustained higher research spending would eventually result in higher annual growth rate for agriculture (Fuglie and Rada, 2013). As also noted by Rada et al., (2013), productivity of agriculture in developing countries, especially Africa must increase to provide the greatest boost to the region's level food security.

Finally, we acknowledge the limitations associated with the data used in the study, especially the use of aggregated data from the FAO database on food availability as a substitute for actual food consumption at national level. This however, may under or over estimate or not reflect actual food consumption pattern. But despite this limitation, we believe the results of the findings conform to the previous macro studies in other region of the world and perhaps similar studies carried out at micro level across the globe.

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TABLES

Table 1: Summary statistics of variables used in the analysis

Variable Define	Description of the variables	Mean	Std. Dev.
FSI Indicators			
i. Per capital Food Available	This is total food available in tonnes divided by country population	10697,28	49539.34
ii. Per capita nutrients available			
-Per capita calories available	Per capita calorie/day available in kilocalories /day/person	2,211.65	303.99
-Per capita proteins available	Per capita g protein/day available in gram g/day/person	55.39	11.19
AP Variables			
i. Agricultural value added /hectare	This is net value of total agricultural production divided by total agricultural land	307.09	670.56
ii. Cereal Production per hectare	This is total cereal production divided by size of land under cereal in hectare	1,226.67	878.09
Z variables			
i. Urban population %	Share of population living in urban areas in percentage	31.80	
ii. Female population %	Share of population that are female in percentage	50.51	
iii. Age < 15 yrs. Population %	Share of population that are < 15 years old in percentage	43.97	
iv. Age > 64 yrs. Population %	Share of population that are > 64 years old in percentage	03.19	
v. Trade openness %	Share of the sum of total imports & exports divided by GDP in percentage	63.97	
vi. Life expectancy at birth	Average life expectancy at birth in years	51.85	7.27
vii. Political right Index	Countries with lack of freedom tend toward 7 & those with freedom tend toward 1	4.68	1.56
viii. GDP_Growth %	Per capita Gross Domestic Product (GDP) growth, 1980-2009 in percentage	5.675	7.736

Table 2: Dynamic specification of the effect of Agricultural productivity on Food Security Levels with one lags depended variables

Explanatory Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 5
	Food Supply	Calorie Supply	Protein Supply	Food Supply	Calorie Supply	Protein Supply
	Coefficient [SE]	Coefficient [SE]	Coefficient [SE]	Coefficient [SE]	Coefficient [SE]	Coefficient [SE]
Lagged_Dependent Variable	0.8815***[0.0562]	0.5914***[0.0646]	0.5903***[0.0605]	0.8087***[0.0512]	0.8453***[0.0749]	0.7662***[0.0583]
LOG[Agricultural value added /hectare]	0.4588***[0.0568]	0.0411***[0.0112]	0.0452***[0.0169]			
LOG[Cereal Production per hectare]				0.4317***[0.0298]	0.0214***[0.0038]	0.0287***[0.0075]
GDP_Growth	0.2796***[0.0502]	0.0832***[0.0211]	0.0459* [0.0273]	0.1918***[0.0689]	0.0983***[0.0262]	0.0276** [0.0100]
Democracy Index	0.0065** [0.0031]	0.0013* [0.0001]	0.0046***[0.0015]	-0.0023 [0.0045]	0.0003 [0.0011]	0.0053***[0.0015]
Life expectancy at birth	0.0022 [0.0027]	0.0015***[0.0005]	0.0023** [0.0010]	-0.0001 [0.0017]	0.0007 [0.0007]	0.0011 [0.0010]
Trade openness	-0.0005 [0.0002]	0.0002***[0.0000]	0.0004***[0.0001]	-0.0003**[0.0001]	0.0001 [0.0001]	0.0004***[0.0001]
Population (0-14 years)	-0.0035 [0.0092]	-0.0000 [0.0045]	-0.0070 [0.0045]	-0.0004 [0.0165]	0.0014 [0.0031]	-0.0007 [0.0031]
Population (64 years above)	-0.1116 [0.0857]	0.0661* [0.0383]	-0.0092 [0.0504]	0.1373 [0.1644]	0.0097 [0.0300]	0.0200 [0.0443]
Urban Population	-0.0081**[0.0035]	0.0012 [0.0012]	-0.0012 [0.0014]	-0.0037 [0.0035]	0.0017* [0.0006]	0.0015 [0.0011]
Female Population	0.0387 [0.1158]	0.0091 [0.0242]	-0.0158 [0.0319]	0.1916***[0.0672]	-0.0045***[0.0160]	0.0035 [0.0208]
Constant	-2.2223 [5.6727]	2.1395 [1.4471]	2.4351 [1.6999]	-11.7063**[3.1825]	1.0927 [1.2171]	0.3728 [1.1272]
# of Countries	41	41	41	41	41	41
# of Periods	30	30	30	30	30	30
Time fixed effect included	YES	YES	YES	YES	YES	YES
Country fixed effect included	YES	YES	YES	YES	YES	YES
AR (1) p-value	0.001	0.001	0.000	0.000	0.000	0.000
AR (2) p-value	0.946	0.419	0.302	0.968	0.448	0.307
Sargan test p-value	1.000	1.000	1.000	1.000	1.000	1.000

*Note: Dependent variables are also expressed in logarithm; ***, **, and * indicate that estimates are significant at 1%, 5%, and 10% respectively.*

Table 3: Linear specification of the effect of agricultural productivity on food security levels

Explanatory Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 5
	Food Supply	Calorie Supply	Protein Supply	Food Supply	Calorie Supply	Protein Supply
	Coefficient [SE]	Coefficient [SE]	Coefficient [SE]	Coefficient [SE]	Coefficient [SE]	Coefficient [SE]
LOG [Agricultural value added /hectare]$_{t-1}$	0.6508***[0.0082]	0.0433***[0.0021]	0.5158***[0.0073]			
LOG [Cereal Production per hectare] $_{t-1}$				0.2132***[0.0041]	0.0200***[0.0012]	0.0082***[0.0005]
GDP_Growth $_{t-1}$	0.0932***[0.0075]	0.0529***[0.0035]	0.0751***[0.0074]	0.1165***[0.0081]	0.0482***[0.0035]	0.0397***[0.0055]
Democracy Index $_{t-1}$	-0.0009 [0.0013]	-0.0008 [0.006]	0.0051***[0.0013]	-0.0015**[0.0017]	-0.0013**[0.0006]	-0.0018**[0.0009]
Life expectancy at birth $_{t-1}$	-0.0022 [0.0016]	0.0044***[0.0004]	-0.0122***[0.0012]	0.0052***[0.0013]	0.0051***[0.0004]	0.0081***[0.0005]
Trade openness $_{t-1}$	-0.0002**[0.0001]	0.0002***[0.0000]	-0.0007***[0.0000]	0.0004***[0.0001]	0.0001***[0.0000]	0.0001***[0.0001]
Proportion of Population (0-14 years)	0.0098***[0.0028]	-0.0021** [0.0011]	-0.0216***[0.0025]	-0.0134***[0.0045]	-0.0043***[0.0010]	-0.0077***[0.0013]
Proportion of Population (64 years above)	-0.0318***[0.0111]	-0.0104* [0.0056]	-0.3496***[0.0109]	-0.1095***[0.0179]	-0.0109***[0.0078]	-0.0097** [0.0045]
Proportion of Urban population	-0.0062***[0.0009]	0.0035***[0.0002]	-0.0040***[0.0009]	-0.0055***[0.0011]	0.0025***[0.0002]	-0.0000 [0.0004]
Proportion of Female population	0.0152 [0.0123]	-0.0114***[0.0045]	-0.3395***[0.0106]	-0.0041 [0.0181]	-0.0183***[0.0036]	0.0054***[0.0063]
Constant	3.0013***[0.6043]	7.8432*** [0.2157]	32.5195***[0.5625]	6.2259***[0.9547]	8.3570***[0.1691]	3.5477***[0.3163]
Time fixed effect included	YES	YES	YES	YES	YES	YES
Country fixed effect included	YES	YES	YES	YES	YES	YES
Autocorrelation type	AR (1)	AR (1)	AR (1)	AR (1)	AR (1)	AR (1)
# of Countries	41	41	41	41	41	41
# of Periods	30	30	30	30	30	30

*Note: Dependent variables are also expressed in logarithm; ***, **, and * indicate that estimates are significant at 1%, 5%, and 10% respectively.*