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ORIGINAL ARTICLE

Pathway to achieving sustainable food security in Sub-Saharan Africa: The role of agricultural mechanization

Godwin Olasehinde-Williams[1] | Festus Fatai Adedoyin[2] |
Festus Victor Bekun[3,4]

[1]School of Economics and Management, Nanchang University, Nanchang, China

[2]Department of Accounting, Economics and Finance, Bournemouth University, Poole, UK

[3]Faculty of Economics Administrative and Social sciences, Istanbul Gelisim University, Istanbul, Turkey

[4]Department of Accounting, Analysis and Audit, School of Economics and Management, South Ural State University, Chelyabinsk, Russia

Correspondence
Festus Victor Bekun, Faculty of Economics Administrative and Social sciences, Istanbul Gelisim University, Istanbul, Turkey.
E-mail: fbekun@gelisim.edu.tr

Abstract

According to the World Health Organization (2020), many parts of the world have demonstrated potentials for acute hunger and famine. Many countries in Sub-Saharan Africa (SSA) actively feature in this category due to geopolical crises and other humanitarian challenges. Despite efforts by SSA governments, agricultural productivity continues to be inadequate in meeting nutritional needs across Africa. Thus, in the presence of economic expansion, vast land, and labor resources, this study investigates the role of mechanization as an important factor for increased agricultural productivity in SSA. Data on 25 SSA countries over 17 years are used. Empirical results from System Generalized Method of Moments show that among other variables, mechanization is a significant factor influencing agricultural productivity. Consequently, in light of the bid for higher agricultural productivity, government investment in mechanization becomes a priority. Also, apart from the fact that many African countries are at the point where more land must be brought under development to satisfy expanded market needs, larger investments in mechanization appear imperative.

1 | INTRODUCTION

In the words of Maximo Torero (2014) of the International Food Policy Research Institute (IFPRI) on World Food Day, "Economic growth is only sustainable if all countries have food security. Without a country-owned and country-driven food security strategy, there will be obstacles and additional costs to global, regional and country-level economic growth."

Food availability has been well established as an important means of attaining sustainable economic growth (Agboola & Balcilar, 2012). It is also seen as crucial to both mental and physical wellbeing of the people in any society (Agboola, 2009). The implication of this is that any food-insecure society is likely to face serious human capital challenges and consequently, growth challenges. This is the major reason why the eradication of malnutrition was a cardinal objective of the United Nations Millennium Development Goals (MDGs) and still is a cardinal objective of the more recently introduced Sustainable Development Goals (SDGs).

Unfortunately, global hunger which steadily declined between 2003 and 2013 has begun to rise again. The number of undernourished people in the world increased from 777 million (10.6% of the world population) in 2015 to 815 million (11% of the world population) in 2016 (FAO, IFAD, UNICEF, WFP, & WHO, 2017). Sub-Saharan Africa (SSA) is the region most affected by this problem of food insecurity; 2015 figures show that about 220 million or 23% of the entire regional population are undernourished (FAO, 2015). This is a lot higher than the global average for the same period, and implies that 1 out of every 4 Sub-Saharan African is undernourished based on the FAO standard of 1800 Kcal intake per day. These figures are projected to further increase to about 355 million people by the year 2050 (African Association for the Study of Regions [AASR], 2014). It is also projected that the regional population will rise to about 1.5 billion by 2050 and that the region will require 360% more food than it produced in 2006 by 2050 (Alexandratos & Bruinsma, 2012). There is therefore a high likelihood that food shortages will continue to worsen except drastic steps are taken to raise agricultural productivity within the region.

Agriculture generates employment for a large share of the SSA population and accounts for a relatively large share of the region's GDP. In spite of its importance to the regional economy, agriculture remains predominantly underdeveloped across the countries of the region. There is therefore very great potential for agricultural expansion in SSA. The limited use of mechanization has been posited as one of the major constraints to the achievement of agricultural development and food security. Agricultural productivity has remained relatively stagnant in the region over the past six decades (Zhou, 2016). The experience of several developing nations of South America and Asia has indicated that it is possible to transform the agricultural sector into a prosperous commercial industry through investment in agricultural machinery. For instance, as a result of the increased productivity associated with investment in agricultural machinery, countries like Brazil, China, and India are now world leaders in agricultural output and exports (FAO, UNIDO, 2008). We thus argue that a similar kind of transformation could be achieved in SSA if mechanization is extensively adopted. Consequently, higher productivity would occur, food security would be achieved, and dependence on food importation will be limited. To empirically confirm this view, this study investigates the impact of mechanization on agricultural productivity and consequently on economic growth using a panel data analysis of 48 Sub-Saharan African countries.

The contribution of this study to extant literature is two-fold. First, this study is among the first set of studies to empirically investigate the theme in a bloc of SSA countries. Second, the study employs the System Generalized Method of Moments (SYS-GMM) panel data

econometric methodology which is known to possess superior merits to time series, given its strength in pooling both cross-sectional and times series dimension (Baltagi & Bratberg, 2005). The GMM approach is robust to the pitfalls such as heteroscedasticity, autocorrelation, and endogeneity commonly associated with conventional panel methods; it also provides reliable estimates for data series with time dimensions smaller than the number of cross-sections (N > T) and assumes that fixed individual effects may be arbitrarily distributed. This aforementioned strength of the methodology adopted implies that the study results are robust and thus suitable for policy direction.

The remainder of this study is structured as follows: Section 2 provides a synopsis of agriculture in SSA and a review of relevant literature, Section 3 describes the methodology followed, Section 4 presents the results and their interpretation, and finally, the concluding remarks and policy directions are presented in Section 5.

2 | AGRICULTURE IN Sub-Saharan AFRICA: AN OVERVIEW

Sub-Saharan Africa has an estimated population of over one billion (World Development Indicators [WDI], 2017) and a land area of approximately 2,455 M hectares, only about 173 m hectares of which are being cultivated. Agriculture in SSA is still dominated by small peasant farmers who use rudimentary tools like hoes and cutlasses, and practice subsistence farming with family members as main source of manpower (Houmy, Clarke, Ashburner, & Kienzle, 2013). According to AASR (2014), these smallholder farmers directly employ about 175 million people. Fertilizer usage is extremely low (Figure 1). The average consumption of fertilizers in 2012 was 14.7 kg per hectare. Average daily income from agriculture is also very low when compared with other regions of the world. Agricultural irrigated land mass is a meager 5% of the total area cultivated.

World Bank (2011) estimates show that SSA experiences yearly losses of about 4 billion dollars in grains production due to wastages in post-harvest handling. As shown in Figure 2, roughly 150 kg of food produced is estimated to be lost per year by each farmer (Consultative Group on International Agricultural Research [CGIAR], 2013). The World Bank's 2013 crop production index shows only a 28.3% increase in the regional crop production over the past decade.

Agricultural irrigation forms the bedrock of mechanization in SSA which has a large potential for smallholder irrigation expansion. Expansion of smallholder irrigation is constrained by water scarcity in many regions. According to Xie, You, Wielgosz, and Ringler (2014), SSA has a potential expandable area of 30 million ha for motor pumps, 24 million ha for treadle pumps, 22 million ha for small reservoirs, and 20 million ha for communal river diversions.

2.1 | Literature review

Agriculture is considered a key driver of economic growth and sustainable development. This position is supported by the physiocracy school of thought, which argues that agriculture is the panacea for long-run economic growth (see Burkett, 2003; Ekelund Jr & Hébert, 2013; Gokmenoglu, Bekun, & Taspinar, 2016; Higgs, 1897; Sertoglu, Ugural, & Bekun, 2017; World
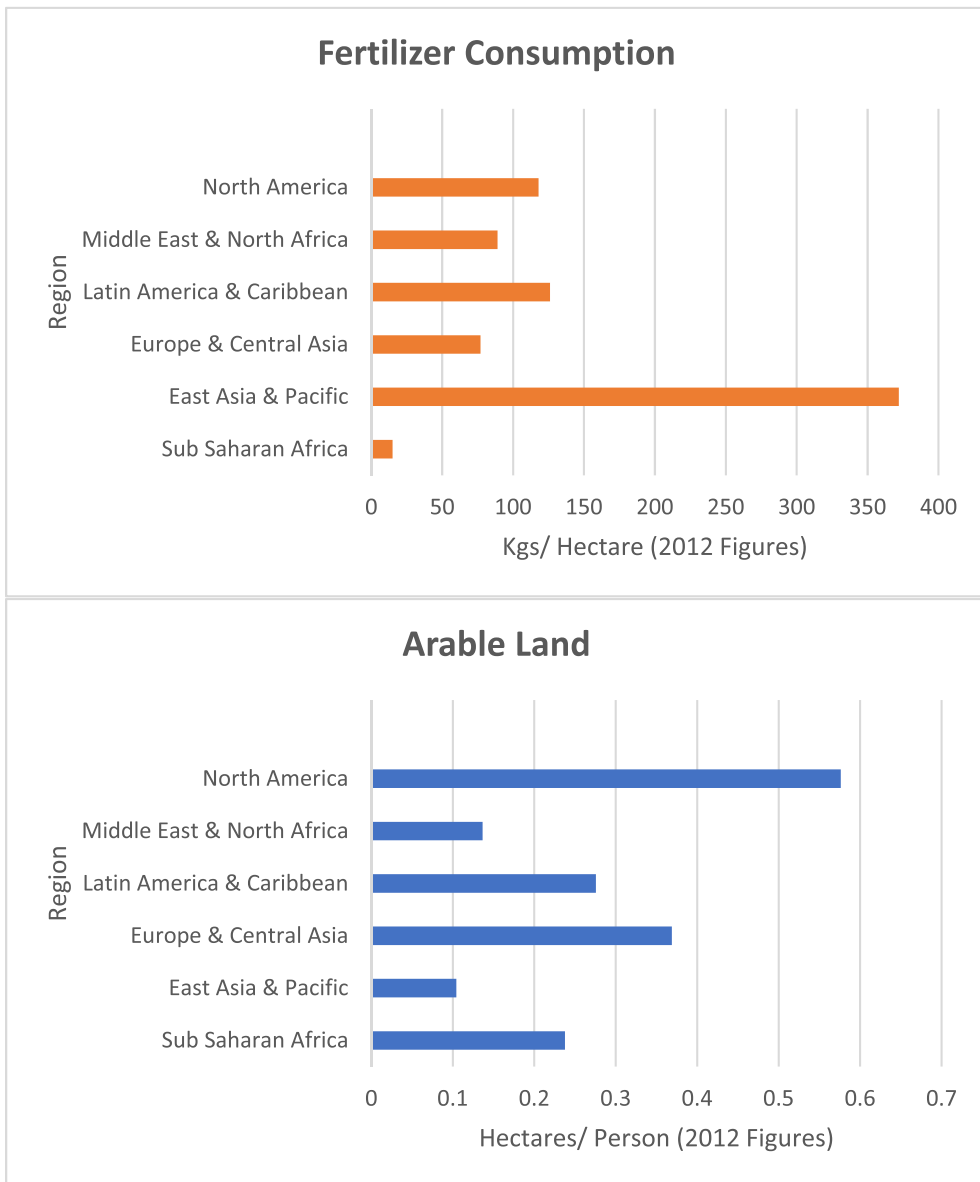
FIGURE 1 Regional comparison of fertilizer consumption and arable land

Bank, 2007). However, how this translates into long-term economic growth has been the bone of contention over time.

The path through which agriculture leads to sustainable, long-run economic growth has been a crucial debate in the agricultural economics literature. According to Agboola and Balcilar (2012), agricultural mechanization plays a key role in the actualization of sustainable economic development, especially in SSA which is plagued by food insecurity. This is so, given the rudimentary mode of operation of most farmers and farm owners in the region. Several scholars support the claim that agricultural mechanization will in the long run translate into increased harvest and reduced post-harvest waste, and also lead to increased income of households and
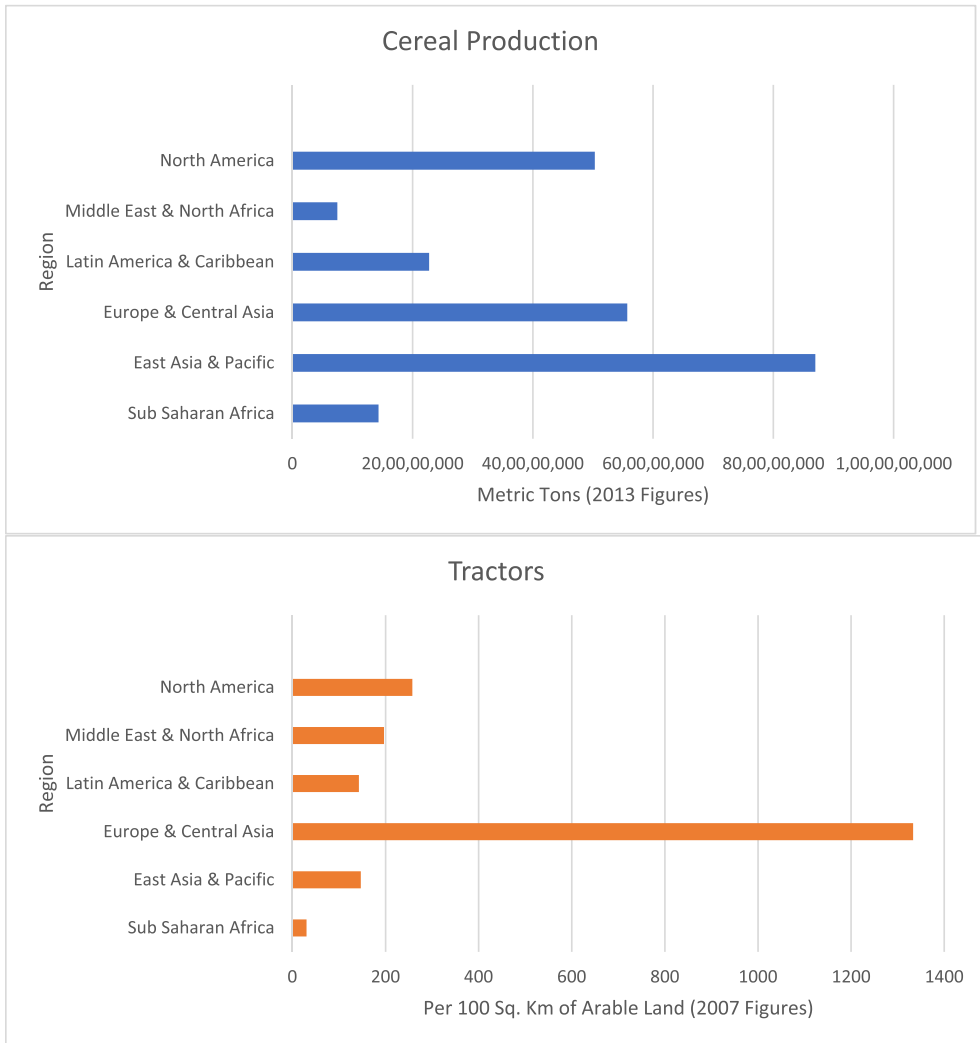
FIGURE 2 Regional comparison of cereal production and tractor (proxy for mechanization)

national output by extension (see Chisango & Dzama, 2013; Lingard & Bagyo, 1983; Rasouli, Sadighi, & Minaei, 2010).

This section gives a brief compendium of agricultural mechanization empirics. The current theme has mixed findings in the existing literature; thus, the need for a stylized outline of the flow of studies is crucial. The bulk of the literature can be classified into two broad groups. The first group posits that mechanization has a positive and significant impact on the agricultural sector. Chaudhry and Hussain (1986) investigate mechanization and agricultural development in Pakistan, and submit that agricultural mechanization results in the following: (a) increased production capacity, (b) cost reduction and output augmentation, and (c) employment creation rather than labor displacing.

The studies of Fulginiti, Perrin, and Yu (2004), Evenson and Avila (2007), and Block (2010) also affirm the positive impact of agricultural mechanization on total factor productivity. They opine that the adoption of mechanization in agricultural operation enhances total productivity and by extension, economic growth. Block (2010) also further argues that the impact of

mechanization could either be direct or indirect. A direct impact can be said to have occurred if mechanization (tractorization) yields increased productivity, whereas mechanization is deemed to have positively impacted agriculture through an indirect channel if it births increases in farmers' income, cost reduction, and increased output, among others. Yu and Nin-Pratt (2011) likewise conclude that agricultural mechanization leads to increased productivity. The authors investigate the evolution of agricultural productivity in SSA through the adoption of Malmquist Index for the period 1984–2006. Their study specifically submits that agricultural mechanization engenders increase in total factor productivity (TFP) as well as production output.

Agricultural specialists and practitioners in recent years have asked if the economic growth generated through agricultural mechanization is sustainable in the long run in SSA. Scholars such as Mrema, Baker, and Kahan (2008) express some level of skepticism in the gains accrued from agricultural mechanization as a result of the reduction in such gains witnessed over the past years in some parts of the continent. The explanation to the above is tied to the decline in tractor-hiring services and also as a result of the deterioration in health care and extension services which lead to outbreaks of diseases in rural areas. Thus, Mrema et al. (2008) and Houmy et al. (2013), among other agricultural specialists and practitioners, along with agricultural agencies like Food and Agricultural Organization (FAO) and International Food Policy Research Institute (IFRI), advocate for policy mix and strategies to revamp agricultural mechanization in SSA.

Zhizhang and Hanlin (2014) examine the effect of agricultural mechanization on the income of farmers in China over the period 1981–2011, using Vector Autoregressive (VAR) and Granger causality test procedure as estimation techniques. Their research lends credence to the positive and significant impact of agricultural mechanization. Saxena (2015) reaches the same conclusion in a study conducted in India. Additional evidence of positive and significant relationship is drawn from the work of Deng, Wang, Mu, and Zhao (2016). The authors employ stochastic frontier analysis (SFA) as opposed to the econometric procedures used in other studies. The study is carried out across 5 provinces in China for 1,690 farmers. The empirical findings support the argument that agricultural mechanization increases technical efficiency and income of farmers. Interestingly, the study also reveals a negative impact when farm size is large. Thus, the authors advocate for accelerated agricultural mechanization in China for increased economic growth.

In a more recent study, Abass et al. (2017) similarly conclude that agricultural mechanization engenders farmer's cassava production in Uganda. Cossar (2019) likewise investigates the impact of mechanization on farming systems and rural economies in Ghana. The study shows that the adoption of agricultural mechanization reduces the toil associated with subsistence agriculture operation which is mostly powered by human muscles. The study is carried out using the 2009–2010 EGC-ISSER survey data, with a focus on examining the short-run impact of machinery supply in the study area. The study validates the short-run positive impact of agricultural machinery supply on agricultural productivity and income.

On the contrary, the second group asserts that the impact of mechanization on the agricultural sector is either insignificant or negative. In a study conducted in Botswana, a country characterized by high Draught Animal Power (DAP), Panin (1995) studies the effect of mechanization on crop production among 127 randomly selected smallholder farmers from 7 districts. The findings reveal that tractor hiring has no impact on total cultivated area, yield of crops, and total output by extension. A study carried out by Benin (2015) on behalf of the Ghana Agricultural Mechanization Service Centre (AMSC) on one hand affirms the positive impact of agricultural mechanization on drudgery reduction and agricultural yield, but on the other hand reveals that agricultural mechanization has no impact on the amount of area plowed. Khaled

and Hammas (2016) also study three Maghreb countries (Algeria, Morocco, and Tunisia) over the period 1997–2012 with a simultaneous equations approach. They find that technological innovation does not translate into sustainable agricultural development. Takeshima, Hatzenbuehler, and Edeh (2020), using panel data from farm households and crop-specific production costs, find that agricultural mechanization is associated with lower economies of scope among non-rice crops in Nigeria.

3 | METHODOLOGY

3.1 | Model

To examine the impact of agricultural mechanization on productivity, a production function is specified for the agricultural sector of SSA. Production functions linking factors of production (land, labor, and capital) with the level of output produced are widely used in empirical studies. For this analysis, mechanization is adopted as the measure of capital, while agricultural land and labor employed in agriculture are used as the measures of land and labor. Significantly large proportions of foreign aid inflows into SSA countries are channeled toward their agricultural sectors in forms that either directly or indirectly impact productivity. Examples include aid for agricultural land, agricultural water, agricultural input, food crop production, agricultural extension, agricultural education and training, agricultural research, agricultural services, agricultural policy and management, and agrarian reforms. We therefore include foreign aid as a control variable. To control for the interconnectedness of the agricultural sectors of SSA countries with those of other countries, we also include agricultural trade openness in the augmented production function. The augmented production function is specified in an econometric form as follows:

$$\text{Model 1}: ATP_{it} = \beta_0 + \beta_1 LAN_{it} + \beta_2 LAB_{it} + \beta_3 MEC_{it} + \beta_4 AID_{it} + \beta_5 ATRA_{it} + \varepsilon_{it} \tag{1}$$

where ATP refers to agricultural productivity, LAN stands for agricultural land, LAB represents labor employed in agriculture, MEC is agricultural mechanization, AID refers to foreign aid, and ATRA represents agricultural trade openness. The logarithmic forms of all the variables are used in our estimations. Our a priori expectation is that all the factors of production will positively impact agricultural productivity as they are all inputs in the production process. Foreign aid is also expected to positively affect productivity, while the impact of agricultural trade openness is indeterminate.

Going a step further, we also empirically examine the impact of agricultural productivity on the economic performance of SSA countries. An econometric model in which real GDP serves as the dependent variable and agricultural productivity serves as an independent variable along with other variables generally regarded as determinants of economic growth according to theory and empirics is specified. The model is given as follows:

$$\text{Model 2}: RGDP_{it} = \beta_0 + \beta_1 TLABF_{it} + \beta_2 GFCF_{it} + \beta_3 TRA_{it} + \beta_4 ATP_{it} + \beta_5 CPI_{it} + \varepsilon_{it} \tag{2}$$

where RGDP is real GDP, TLABF is the total labor force, GFCF is gross-fixed capital formation, TRA is trade openness, and CPI is consumer price index. All the variables are used for analysis in their logarithmic forms. In terms of a priori expectations, all the variables except CPI are expected to positively impact GDP.

3.2 | Data

This study adopts a panel data which is balanced and covers the period 1991 to 2007[1] for 25 Sub-Saharan African countries (Benin, Botswana, Burkina Faso, Cape Verde, Cameroon, Congo Dem. Rep, Congo Rep, Gabon, Gambia, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Nigeria, Rwanda, Senegal, South Africa, Togo, Uganda, Zambia, and Zimbabwe). In Table 1, we provide a description of the variables used in the empirical analysis and their respective sources.

3.3 | Estimation technique

The study adopts a dynamic panel model in estimating the effect of mechanization on agricultural productivity in Sub-Saharan Africa as specified in model 1 (Equation (1)), and the effect of agricultural productivity on real GDP as specified in model 2 (Equation (2)). The use of panel data models in applied economics as well as dynamic panel estimation techniques are more befitting in capturing the dynamic behavior of economic relationships considering the structure of the data (Adedoyin, Abubakar, Victor, & Asumadu, 2020; Adedoyin,Cheol, Adeniyi, & Kabir, 2017; Adedoyin, Bekun, & Alola, 2020b; Adedoyin, Alola, & Bekun, 2020a; Adedoyin, Gumede, Bekun, Etokakpan, & Balsalobre-lorente, 2020c). This model is closer to reality than any other panel model of estimation (Olubusoye, Salisu, & Olofin, 2016). A typical dynamic panel model is specified as follows:

$$y_{it} = \delta y_{it-1} + X'_{it}\beta + u_i + \eta_{it} \tag{3}$$

where y_{it} is the regressand for individual country i over the period t, X'_{it} is the matrix of exogenous variables for individual country over the period t, u_i is the individual country-specific effect, and η_{it}, the remainder disturbance term.

According to Baltagi and Bratberg (2005), dynamic model is characterized by two sources of persistency over time. First, autocorrelation resulting from the inclusion of lagged dependent variable as an explanatory variable. That is, δy_{it-1} is correlated with error term η_{it} ($E(\delta y_{it-1}, \eta_{it} \neq 0)$). Second is the unobserved main effects and interaction effect which characterizes the heterogeneity among units. One of the important methods of estimating dynamic panel data models especially when dealing with many countries (N) and within a short time period (T) is the Arellano and Bond Generalized Method of Moment (GMM) (AB-GMM). Consequently, in Section 4, the variables in Equations (2) and (3) are estimated using AB-GMM approach. Specifically, the system-GMM estimator is employed in the analyses. This is due to its recorded improved efficiency gains over the alternative first-difference estimator (Baltagi, 2008). The more efficient two-step variant of the GMM-estimator is also employed. The lagged values of dependent and independent variables in level form serve as the instruments.

3.4 | Diagnostic tests

Arellano and Bond (1991) proposed two tests to validate the estimation. First is that there is no second-order serial correlation for the remaining disturbances of the differentiated equation. This is an essential condition as the consistency of GMM estimator rests on the assumption

TABLE 1 Description of variables

Variable	Definition	Source
Agriculture, forestry, and fishing, value added (constant 2010 US$) *ATP*	Agriculture corresponds to ISIC divisions 1–5 and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources.	World Bank national accounts data, and OECD National Accounts data
RGDP (constant 2010 US$) *RGDP*	Real GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 US dollars.	World Bank national accounts data, and OECD National Accounts data
Agricultural land (% of land area) *LAN*	Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures. Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow.	Food and Agriculture Organization (FAO)
Employment in agriculture (% of total employment) (modeled ILO estimate) *LAB*	Employment is defined as persons of working age who were engaged in any activity to produce goods or provide services for pay or profit, whether at work during the reference period or not at work due to temporary absence from a job, or to working-time arrangement.	International Labour Organization, ILOSTAT database
Agricultural mechanization (1000US$) *MEC*	Agricultural mechanization refers to the number of wheel and crawler tractors (excluding garden tractors) in use in agriculture at the end of the calendar year specified or during the first quarter of the following year.	Food and Agriculture Organization data
Foreign aid (Constant 2018 US$) *Aid*	Foreign aid refers to the total official development assistance inflow to recipient countries. It covers the volume, origin and types of aid to the selected SSA countries. The data is computed through the aggregation of information obtained from DAC members of OECD, non-DAC donor countries and international organizations.	OECD Official Development Assistance data
Agricultural trade openness (share of GDP) *ATRA*	Agricultural trade openness is the addition of agricultural exports and imports measured as a share of gross domestic product.	Food and Agriculture Organization data

(Continues)

TABLE 1 (Continued)

Variable	Definition	Source
Labor force, total *LNTLABF*	Labor force comprises people aged 15 and older who supply labor for the production of goods and services during a specified period. It includes people who are currently employed and people who are unemployed but seeking work as well as first-time jobseekers. Not everyone who works is included, however. Unpaid workers, family workers, and students are often omitted, and some countries do not count members of the armed forces. Labor force size tends to vary during the year as seasonal workers enter and leave.	International Labour Organization, ILOSTAT database.
Gross fixed capital formation (constant 2010 US$) *GFCF*	Gross fixed capital formation (formerly gross domestic fixed investment) includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. According to the 1993 SNA, net acquisitions of valuables are also considered capital formation. Data are in constant 2010 US dollars.	World Bank national accounts data, and OECD National Accounts data files.
Trade (% of GDP) *TRA*	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	World Bank national accounts data, and OECD National Accounts data files.
Consumer price index (2010 = 100) *LNCPI*	Consumer price index reflects changes in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly. The Laspeyres formula is generally used. Data are period averages.	International Monetary Fund, International Financial Statistics and data files.

that $E(\Delta\eta_{it} - \Delta\eta_{it-2}) = 0$. It should be noted that first order is expected in the first differenced dynamic panel data models. Therefore, we reject null hypothesis of no autocorrelation for AR (1) and accept null hypothesis for AR (2). Second is the instrument validity test. This becomes necessary because of the potential correlation between the lagged dependent variable and the remainder of the disturbance term (Olubusoye et al., 2016). In order to determine the validity of the instruments used, the Sargan test of over-identifying restrictions is employed. For these two tests, we must accept the null hypothesis of validity of instruments (Roodman, 2009).

4 | RESULTS AND DISCUSSION

Country-level summary statistics is presented in Table 2 (see appendix Tables A1 and A2 for summary statistics of model 2). This is vital in order to highlight the variable averages over the period considered as well as the dispersion of each variable from its mean. For agricultural productivity,

TABLE 2 Summary statistics

Country	LNATP Mean	SD.	LNRGDP Mean	SD	LNMEC Mean	SD	LNLAN Mean	SD	LNLAB Mean	SD
Benin	20.75	0.26	22.22	0.23	4.11	1.60	3.26	0.16	3.81	0.03
Botswana	19.25	0.09	22.81	0.23	6.62	0.46	3.82	0.00	2.96	0.15
Burkina Faso	21.30	0.25	22.30	0.29	3.52	0.88	3.61	0.06	4.36	0.13
Cabo Verde	18.07	0.40	20.45	0.48	4.72	0.70	2.88	0.04	2.91	0.13
Cameroon	21.65	0.21	23.58	0.18	5.91	0.88	2.97	0.00	4.18	0.04
Congo, Demo	22.14	0.07	23.51	0.13	6.44	1.00	2.43	0.01	4.27	0.03
Congo, Rep	19.56	0.15	22.76	0.13	5.25	1.05	3.43	0.00	3.69	0.02
Gabon	20.11	0.11	23.26	0.07	5.49	0.83	3.00	0.00	3.75	0.02
Gambia, The	18.89	0.20	20.24	0.17	3.31	0.70	3.98	0.05	3.42	0.01
Kenya	22.74	0.15	23.99	0.15	7.71	0.59	3.85	0.01	3.93	0.11
Lesotho	18.59	0.13	21.18	0.16	4.02	1.43	4.34	0.00	4.28	0.01
Madagascar	21.30	0.10	22.58	0.14	5.11	0.80	4.20	0.05	4.36	0.02
Malawi	21.08	0.30	22.13	0.17	6.03	1.07	3.90	0.08	4.34	0.01
Mali	21.46	0.17	22.54	0.26	5.19	0.87	3.42	0.08	4.23	0.02
Mauritania	20.31	0.08	21.72	0.20	2.53	1.35	3.65	0.00	4.12	0.02
Mauritius	19.59	0.08	22.55	0.23	6.45	0.42	3.91	0.05	2.48	0.15
Mozambique	21.04	0.33	22.18	0.44	5.76	1.35	4.12	0.01	4.41	0.03
Nigeria	24.33	0.41	25.93	0.25	9.17	1.11	4.33	0.04	3.87	0.05
Rwanda	20.58	0.35	21.70	0.34	4.00	0.96	4.24	0.08	4.46	0.05
Senegal	21.18	0.10	23.08	0.20	6.14	0.64	3.82	0.02	3.87	0.05
South Africa	22.66	0.11	26.30	0.16	9.85	0.62	4.39	0.01	2.26	0.17
Togo	20.68	0.15	21.61	0.15	3.11	1.11	4.14	0.04	3.62	0.03
Uganda	22.10	0.17	22.96	0.34	5.53	1.34	4.14	0.04	4.26	0.02
Zambia	21.47	0.15	23.04	0.21	6.87	0.74	3.39	0.03	4.27	0.01
Zimbabwe	21.41	0.20	23.42	0.17	7.21	0.68	3.64	0.07	4.13	0.05

notably large economies (Nigeria, Kenya, South Africa, DRC Congo, and Uganda) all have very high averages over the period considered. However, although not entirely surprising, the smaller economies such as Lesotho, Congo Republic, and Cape Verde all have relatively low agricultural productivity over the period considered. In terms of mechanization, of the five large economies from our sample, South Africa, followed by Nigeria, lead the volume of average investment in agricultural mechanization over the period.

The Pearson correlation coefficient is a proportion of the quality and bearing of affiliation that exists between two variables and draws a line of best fit through the information of the two factors. From Table 3, a significant positive relationship exists between real GDP and agricultural productivity. This is higher than labor, land, and agricultural mechanization, but all have statistically significant and positive relationships with agricultural productivity in Sub-Saharan Africa.

Table 4 presents the results from the two-step system GMM estimations. The results show that agricultural mechanization (MEC) has a positive and significant impact of agricultural

TABLE 3 Correlation matrix

	LNATP	LNRGDP	LNMEC	LNLAB	LNLAN
LNATP	1				
LNRGDP	0.806*	1			
	0.000				
LNMEC	0.547*	0.774*	1		
	0.000	0.000			
LNLAB	0.261*	−0.176*	−0.288*	1	
	0.000	0.0003	0.000		
LNLAN	0.153*	0.109*	0.096*	−0.068	1
	0.002	0.025	0.047	0.165	

productivity (ATP). The findings indicate that a one-percent increase in mechanization is able to increase productivity by 0.004%. This is in line with the findings of Diao, Silver, and Takeshima (2016). Importantly, given the moderately high land-to-work proportion on agrarian resources in numerous African nations, mechanization may assume a more noteworthy impact in African agricultural productivity than in other parts of the world. For example, in most Asian nations, the land-to-labor proportion is low, and rustic non-farm business openings are not many. However, in certain African nations, such as Ghana, Nigeria, Senegal, and Zambia, the land is richer than in numerous Asian nations.

In many SSA countries, rural–urban drift has increased significantly, reducing agricultural labor. Thus, mechanization has become more important than ever before. Specifically, the movement to the urban territories has expanded work openings in non-farm benefits in the rural regions. This could put pressure on provincial (rural) wages, in addition to the fact that horticultural land profitability, estimated by yield, is still very low in most African nations. As a result of these, there is need for the adoption of work-sparing innovation and mechanization capable of causing a fundamental boost in agricultural productivity in SSA. It is thus conceivable that the absence of mechanization restricts the potential increase in productivity. For example, improved seeds and utilization of manures and pesticides require adequate mechanized agricultural processes in order to overcome food shortages.

Concerning the control variables in model 1, in line with economic theory and empirics, agricultural land (LAN), labor employed in agriculture (LAB), and foreign aid (AID) exhibit positive and significant relationship with agricultural productivity (ATP). A percentage increase in LAN is able to raise ATP by about 0.05%, a percentage increase in LAB is capable of raising ATP by about 0.073%, and a percentage rise in AID is able to increase ATP by about 0.016%. Agricultural trade openness (ATRA), on the other hand, displays a negative and significant relationship with agricultural productivity. Specifically, a percentage increase in ATRA will cause ATP to decline by about 0.042%. This is an indication that SSA countries are heavily dependent on the rest of the world for agricultural supplies. The results also show that the level of productivity in previous periods positively impact the current level of productivity. One period lagged effect of productivity leads to a 0.954% increase in productivity in the following period.

The system GMM estimation results for model 2 are also reported in Table 4. The results reveal that a one-percent increase in agricultural productivity (ATP) leads to about 0.069%

TABLE 4 System GMM estimation results

Model 1 dependent variable = ATP		Model 2 dependent variable = RGDP	
Variables	**Coefficients**	**Variables**	**Coefficients**
ATP_{t-1}	0.954***	$RGDP_{t-1}$	0.051***
	(.000)		(.000)
LAN	0.050**	ATP	0.069**
	(.029)		(.035)
LAB	0.073**	TLABF	0.162***
	(.023)		(.000)
MEC	0.004**	GFCF	0.798***
	(.045)		(.000)
AID	0.016**	TRA	0.255***
	(.013)		(.000)
ATRA	−0.042***	CPI	0.034***
	(.002)		(.000)
Constant	−0.059	Constant	1.251***
	(.880)		(.000)
Observations	397	Observations	277
Number of crossid	25	Number of crossid	17
Sargan test	19.973	Sargan test	16.757
Sargan Prob	0.893	Sargan Prob	0.298
AR (1) test	−3.037	AR (1) Test	−3.542
AR (1) *p*-value	.002	AR (1) *p*-value	.004
AR (2) Test	1.234	AR (2) Test	0.895
AR (2) *p*-value	.217	AR (2) *p*-value	.370

Note: (1) *p*-values in parentheses. (2) ***$p < .01$, **$p < .05$, *$p < .1$.

increase in real GDP (RGDP). Also, in accordance with economic theory and empirics, labor force (TLABF), gross fixed capital formation (GFCF), and trade (TRA) all have positive and significant impacts on real GDP. An increase in TLABF by 1% increases RGDP by 0.162%. A 1% increase in GFCF increases RGDP by 0.798%. One percent increase in TRA increases RGDP by 0.255%. A percentage increase in CPI raises RGDP by 0.034%. The results also suggest that RGDP in previous periods positively impacts the current level of RGDP. One period lagged effect of RGDP leads to 0.051% increase in RGDP in the following period. In both models, the Sargan tests for instrument validity show that the null hypothesis that instruments are valid should be accepted. Both models also pass the second order autocorrelation test.

5 | CONCLUSION AND POLICY RECOMMENDATION

The importance of agriculture and its determinants to the wealth of nations has been keenly studied over time. For example, going as far back as the 18th century, the physiocrats already

recognized the importance of agricultural land in the growth process of nations. Mechanization is however one very vital input for agricultural production process that has been historically overlooked by SSA countries. Increased level of mechanization has been identified as a route to achieving agricultural productivity, which is also one of the aims of the SDGs (zero poverty and food security). Agricultural mechanization reduces drudgery, relieves labor shortages as well as enhances productivity and timeliness of agricultural operations. Also, the use of new eco-friendly technologies provides an avenue for farmers to produce crops more efficiently by using less power. Agricultural mechanization also contributes immensely to the growth of value chains and food systems by bringing about efficiency in post-harvest, processing and marketing activities.

It is on the basis of the identified potential benefits of mechanization that this study sought to assess the impact of agricultural mechanization on agricultural productivity in a bloc of SSA countries. This study also answers a key policy question by providing insights into the extent to which agricultural productivity contributes to economic growth in Africa. This study differs from that of Houmy et al. (2013) and Adetutu and Ajayi (2020) who both assessed agricultural mechanization in SSA, but only focused on the scientific process of agricultural mechanization and the role of research and development expenditures respectively. To achieve the set objective, this article employed the system-GMM methodology in analyzing a panel of 25 SSA countries over 17 years.

The implications of the findings of this study are far-reaching. To start with, food security seems plausible with increased machinery. The results show that mechanization is a significant factor influencing agricultural productivity in Sub-Saharan Africa. The result shows that a percentage increase in mechanization leads to 0.004% increase in productivity. This confirms that increased mechanization increases real productivity in SSA. The relatively small coefficient size however indicates that the impact is still negligible, suggesting that extensive investment in mechanization is required in the region. This outcome is consistent with the study of Nin-Pratt and Yu (2011).

Consequently, in light of the bid for higher agricultural productivity, government investment in mechanization becomes a priority. Mechanization is thus suggested as a key segment of the innovation required to raise agricultural productivity. Also, apart from the fact that many African countries are at the point where more land must be brought under development to satisfy expanded market needs, or when existing area must be more seriously developed (which requires more mechanization per unit of land), larger investments in mechanization seems imperative. In summary, the need for policies that support higher levels of investment in mechanization cannot be overemphasized.

ORCID

Festus Fatai Adedoyin https://orcid.org/0000-0002-3586-2570

ENDNOTE

[1] The choice of time frame and number of countries is mainly due to data availability, particularly that of our variable of interest—agricultural mechanization—which is extracted from the Food and Agriculture Organization (FAO) database.

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AUTHOR BIOGRAPHIES

GODWIN OLADEHINDE-WILLIAMS is a faculty member at the University of Ilorin. He has published widely in the fields of energy, insurance and agriculture.

FESTUS FATAI ADEDOYIN is a researcher at the Department of Accounting, Economics and Finance, Bournemouth University, UK. His current research focuses on the effect of taxation on tourism demand. His research interest includes tourism and environmental economics.

FESTUS VICTOR BEKUN holds a PhD in energy and environmental economics. Currently serves as an Assistant Professor at Istanbul Gelisim University, Istanbul Turkey. My research interest includes energy and environmental economics, environmental tourism and Agricultural production and efficiency. My previous papers appear in top tier index journals namely European Journal of Tourism Research, Resources policy, Energy and Environment, Science of the total environment among others.

APPENDIX

TABLE A1 Summary statistics for variables used in model 2

Variable	Obs.	Mean	*SD*	Min	Max
CPI	384	54.979	24.365	9.31E-09	94.141
LNRGDP	425	22.754	1.330	19.604	26.605
LNGFCF	349	21.131	1.419	17.845	24.993
LNTRA	403	4.095	0.398	3.138	5.086
LNATP	425	20.931	1.374	17.315	25.013
LNTLABF	425	14.857	1.387	11.650	17.711

TABLE A2 Pairwise correlation matrix for variables used in model 2

	LNRGDP	LNTLABF	LNGFCF	LNTRA	LNATP	CPI
LNRGDP	1					
	—					
LNTLABF	0.698*	1				
	0.000	—				
LNGFCF	0.963*	0.505*	1			
	0.000	0.000	—			
LNTRA	−0.202*	−0.613*	−0.101	1		
	0.000	0.000	0.066	—		
LNATP	0.793*	0.922*	0.652*	−0.579*	1	
	0.000	0. .000	0.000	0.000	—	
CPI	−0.125*	−0.287*	−0.066	0.244*	−0.239*	1
	0.014	0.000	0.235	0.000	0.000	—