Original Research Article

Output Growth of Uganda's Agriculture Sector. Does Public Expenditure on Education Matter?

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ABSTRACT

We examine the multiple dimensions of the effect of public investment in education on agriculture sector output in a multivariate econometric framework. The study is underpinned by the growing interest in empirical investigations on the effects of public education expenditure on economic growth in developing countries to inform the education sector policy environment. The research employed a longitudinal study approach to examine the extent of public investment in education and effects on agriculture sector output in Uganda. The study relied on data from national statistics for the period 1982- 2017. Overall, public expenditure on education has a net positive effect on agriculture sector output. The impact of education on agriculture output has been proven to promote agriculture output through supporting farmer adoption of new productivity-enhancing technologies.

Keywords: Auto-Regressive Distributed Lag (ARDL), Agriculture output, Education, Public Expenditure, Economic Growth)

1. INTRODUCTION

Investigations of human capital development through tracking public expenditure on education in developing countries are gaining traction from researchers, policymakers, and development economists alike. Financial capital for long has been considered the scarcest resource in an organization. In this regard, various strategies are in place to ensure optimisation of returns at organisation level. However, in the new paradigm of "knowledge economy" the scarcest resource is human capital, and the conventional measurement systems used to ensure maximum returns on human capital results in misallocation of resources (Angrist *et al*., 2019).The causal linkage between education, human capital development and economic growth is an issue that has both theoretical and practical significance. Human capital accounts for up to a third of cross-country income differences and is therefore a vital ingredient of economic growth (Abrigo *et al*., 2018). According to the World Bank blog "*why education matters for economic development*", the estimated value of human capital is 62% of the total global wealth. This value is four times the combined value of produced physical capital and natural resources (Patrinos *et al*., 2017). Despite the long lag period, increasing investment in human capital leads to reduction in poverty and this effect is most significant in poor countries(Collin and Weil, 2020).

Gillman, (2019) in his essay on “human capital theory of structural transformation” postulates that with investment in human capital, it is possible to have sectoral transformation along with a balanced growth path equilibrium accompanied by gradual shifts over time from less human capital-intensive sectors towards more human capital-intensive sectors. This transition and mobility of human capital within an economic ecosystem leads to significant economic output arising from increased productivity per worker and technological progress (Bloom *et al*., 2020; Galor and Tsiddon, 1997). The increment in demand for knowledge in the production processes simultaneously leads to rapid human capital driven economic growth (Cebeci *et al*., 2015).Therefore, a better understanding of the relationship between investments in education and agriculture sector growth for an agriculture-dependent country like Uganda that has over 70% of its labour force directly employed in the agriculture sector is critical.

Education is an important variable in human capital development as the country’s stock of skills immensely matters in its prosperity and growth rate (Burgess, 2016). Education as an investment enriches people's understanding, improves the quality of their lives, and leads to broad social benefits at both individual and societal level (Barbiero and Cournede, 2013; Kucharčíková, 2014). The study of human capital serves multiple purposes of understanding the drivers of economic growth, assessing the long-term sustainability of the country's development trajectory and more importantly, to measure effects and productivity of the education sector (Liu, 2014; Nowak and Dahal, 2016)**.** That said, there is little attention given to Uganda’s examination of the causal relationship between economic growth and human capital development within a multivariate framework. The centrality of human capital in an ever-increasing space of “knowledge economy” places strong connections between education and training, and acquisition of 21st Century skills to ensure that individuals thrive in a constantly changing environment where learning never stops.

The importance of the education sector is unquestioned, yet measures of its effect on economy sector output remains less studied and yet it is the critical pathway in human capital formation (Diagne and Diene, 2011). A country’s human capital development success is dependent on policy and public investment choices underpinned by the age structure of its population. Uganda’s age structure is a paradox of its own. Census data indicates that close to 63% of the total population is below the age of 24 years and 50% below the age of 15 years (UBOS 2018). This young population demands purposive skilling and knowledge formation to enable them find meaningful and inclusive engagement in the economy (Mberu *et al*., 2016). Based on these demographic statistics, the country is characterised as “young”. Han and Lee, (2019) argues that countries with significantly larger proportion of young populations under the age of 15 years, as for the case of Uganda, need to invest more in human capital development. While those with older populations where the greater proportion of the population is 65 years and above need to invest more in the health sector as the consequence of ageing kicks in. Uganda has less than 2% of the total population above 65 years of age and this fact underpins the need to invest in education.

This paper attempts to describe a simplified method of estimating the relationship between investments in Human Capital Development and Agriculture sector growth using the Autoregressive Distributed Lag (ARDL) regression model. The purpose is to test and estimate the long-run relationship between Public expenditure in education, Physical Capital accumulation and labour force on agriculture sector output for the period 1982 to 2018. The article seeks to add to the ongoing free market belief that public investment is wasteful and to a larger extent less efficient even if it is in the field of education (Landau, 1983). Particular, attention is paid to growth in labour, public investment at primary, secondary and tertiary level and physical capital accumulation. This article is organised as follows; literature review, data sources, empirical estimation, results, and concludes with recommendations to guide future public investment priorities and policy direction.

LITERATURE REVIEW

The study of human capital serves multiple purposes of understanding the drivers of economic growth, assessing the long-term sustainability of the country's development trajectory and more importantly, to measure output and productivity of the education sector (Liu, 2014; Nowak and Dahal, 2016). Such studies help improve the fitness of growth models which have explanatory variables of physical capital, education investment and labour inputs in explaining the level of economic development and growth disparities across countries (Sunde and Vischer, 2015). Indeed Galor and Moav (2004) posits that replacement of physical capital accumulation by human capital accumulation as a main driver of growth is critical for economies to transition from industrial revolution era to modern growth. Despite the multifaceted definition of human capital, which includes several aspects of education, training, and health, this paper is restricted to public expenditure on education at three levels of education, i.e. primary, secondary and tertiary. This follows persistent calls for African countries to prioritise primary education catastrophically at the expense of tertiary education as the estimated returns to the former are higher (Psacharopoulos and Patrinos, 2002). Education is a key input into the research, development and innovation sub-sector that produces new knowledge and products that translate into economic outputs (Hanushek, 2013). Education raises people's productivity, creativity, promotes entrepreneurship and technological advancement of humankind leading to output growth (Schutt, 2003). A decennial review of global literature on returns to education from 139 countries for the period 1954-2014 reveals that the private average global return to a year of schooling is 9% per year, while social returns to school remain much higher especially in developing countries (Psacharopoulos and Patrinos, 2018). These estimates of private returns to education are in tandem with earlier cross-country estimates of 10% per year (Patrinos and Montenegro, 2014). Critically, women continue to experience higher returns facilitated with spaces gender equality. (Orisadare *et al*., 2017). Whereas the neoclassical growth theory postulates that physical capital and labour are the critical pathways through which economic growth could be achieved, the new growth theories contend that human capital accumulation is a fundamental determinant of a nation’s economic growth due to increase in productivity and technological innovation (Duan, 2019; McDonald and Roberts, 2002; Nnyanzi and Kilimani, 2018).

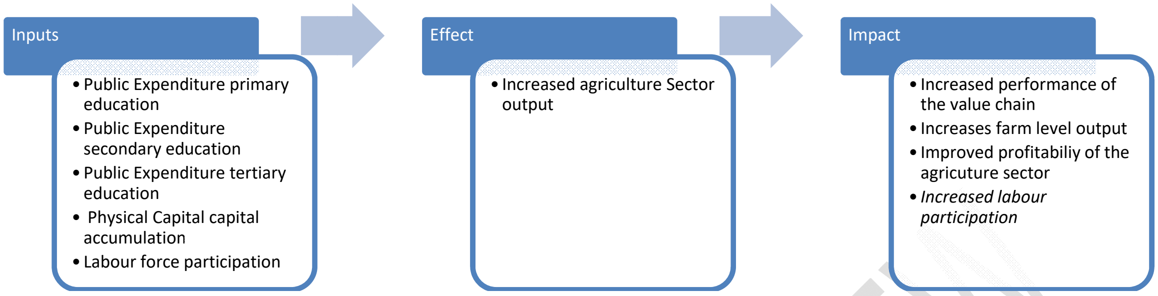
The Human Capital Theory considers education as an investment with both long-run and short-run effects on economic growth rather than a consumptive policy decision (Clarke and Gholamshahi 2018; Gillies 2016; Li and Wang 2016; Sefa *et al*., 2015).

At the national level, it is the qualified and skilled individuals, rather than its physical capital and material resources that determine the character and pace of economic growth (Aremu 2014). There is extensive literature that attributes the phenomenal growth of most of the Asian countries to deliberate and intensive investment in human capital development that led to the accumulation of skilled and employable labour force with innovative capacities and high productivity translating to economic growth (Azam and Ahmed, 2015; Maitra, 2016; Pegkas, 2014; Reza and Valeecha, 2012). Human Capital is an accelerator of scientific, technological progress and innovation. At the societal level, education is crucial in securing economic and social progress and reducing inequality through improving income distribution (Kabir Usman 2019; Ma, 2019). The recent economic downturn coupled with the saturation of the business market in a globalised economy has pushed firms to realise the importance of human capital (Lim *et al*., 2018). At a firm level, investment in human capital development is a critical factor that pushes the competitive edge and innovation envelope maximising returns on investment (Antonelli and Colombelli, 2015; Pol and Rameshkoumar, 2016).

It is critical to note that agriculture plays a critical role not only in the survival of people but also in the well-being and economic prosperity of nations. For this very reason, the sector occupies a conspicuous space among the United Nations (UN) Sustainable Development Goals (SDGs). At sectoral level and specifically for the agriculture sector, there is evidence that many modern technologies have met with only partial success, as measured by observed rates of adoption (Singh and Sharma, 2004). It is postulated that Human Capital directly influences agricultural productivity by affecting how inputs are used and combined by farmers, improves the efficiency of acquisition, assimilation and implementation of new technology, with the that are efficient (Huffman, 2002). The conventional wisdom to this lack of rapid adoption of innovations has been attributed to the usual suspects, namely; lack of credit, limited access to information, risks in the sector, and land fragmentation, while conveniently forgetting the insufficient human capital that has failed to adopt the new innovative rural outreach models (Signh and Sharma, 2004; Tsai *et al*., 2010). Technological change in agriculture plays a critical role in transformation of the sector but this requires substantial investment (Dietrich *et al*., 2014). There is evidence that under-investment in education will constrain the skills, knowledge, and competency leading to the economic stagnation of a country(Fraumeni, 2000;Sianesi and Reenen, 2003;Bakkabulindi, 2006; Bloom *et al*., 2014; Katunguka, 2015;Marginson, 2015 andMarginson 2017). . At the sector level, growth and prosperity are positivelycorrelated to a reduction in rural poverty that is still a characteristic of an agriculture-dependent household (Arndt et al., 2016).

Therefore, we examine the multiple dimensions of the effect of public investment in education on agriculture sector output in the multivariate econometric framework. The re-examination of the level of investment in human capital development and agriculture sector output is imperative, and this study is poised to unravel this problem and add to the existing literature in this area. Below is the conceptual framework

Fig 1. Conceptual framework



Material and Methods

Data description

Data were drawn from national accounts statistics. Relevant permission was obtained from the Uganda Bureau of Statistics (UBOS) to access and use data that is not in the public domain. Additional data were obtained from Annual statistical abstract publication for the period 1982 to 2018, UNESCO statistics for education statistics, ILO for employment statistics.

Public expenditure on education expressed in monetary terms at 2010 constantUSD is defined as the current, capital, and transfers at both national and local governments' level. It critical to note that Uganda public financing mechanism is decentralised with local governments playing a significant role at the primary level of education. This. This expenditure also includes transfers from international sources to the government in support of the education sector In this paper we segregate the public expenditure at primary level (*prim*), Secondary level (*Sec*) and Tertiary level (*Tert*). The latter also includes public expenditure on vocational training.

*The labour force (L)*is defined as the sum of persons of working age 15-64 years who furnish the supply of labour for the production of goods and services. However, in the context of this study this definition explicitly refers the sum of all persons of working age employed in industry, service and agriculture sectors.

*Agriculture output (AGRI)*variable is defined as 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. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3 or 4. Data are in constant 2010 U.S. dollars.

Physical capital formation (K) variable is defined as a real capital stock, which represents gross fixed capital formation and increases in stocks (e.g., buildings, equipment, and other infrastructure) in the domestic economy. This series is also measured US dollar at 2010 constant prices.

The ARDL Econometric Model

The econometric model takes the form of augmented Cobb-Douglas function within labour augmented theoretical framework that considers human capital as an independent factor of production Mankiw *et al.*, 1992).

$$AGRI_t = K_t^{\alpha} H_t^{\beta} (AL)_t^{1-\alpha-\beta} \tag{1}$$

Where *α< 0, β>0, α + β < 1*

Where *AGRI* is output, *K* is physical capital, *H* is human capital, *L* is labour number of works the country and *A* level of technology. The $(AL)_t$ component implies the effective units of labour; α is the elasticity of capital with respect to *AGRI*, *β* is the elasticity of human capital with respect to *AGRI*. The model assumes that *α + β < 1*, which implies a diminishing, return to capital. Based on the above Human Capital (*H*) is substituted proxies; public expenditure in Primary Education (*Prim*), Secondary Education (*Sec*) and Tertiary Education referring to post-secondary education level to include university level and Business and Technical Vocational T (*Tert*). After substituting the instrumental variables in the equation above and taking the natural logarithm, the above the following equation is derived.

$$ln\ AGR_t = \alpha lnK_t + \beta lnH_t + (1-\alpha-\beta)\ \ ln\ (AL)_t + \varepsilon_t \tag{2}$$

Further, substituting H proxies *Prim, Sec* and *Tert,* the above equation can be rewritten as below.

$$lnAGRI_t = \alpha lnK_t + \beta(lnPrim_t + lnSec_t + lnTer_t) + (1-\alpha-\beta)\ \ ln\ (AL)_t + \varepsilon_t \tag{3}$$

From the equation above, the equation below is derived to estimate both long-run and short-term regressions using $\emptyset_i$ and β_i respectively, as applied by Ifa & Guetat, (2018); Orisadare *et al.*, (2017). Where, are the short –run coefficients. The error correction terms are assumed to lie within 0-1.

ARDL Model specification

$$\Delta lnAGR_t = \propto_0 + \sum_{i=1}^{n} \emptyset_1 \Delta lnYAGR_{t-1} + \sum_{i=1}^{n} \beta_1 lnAGR_{t-1} + \sum_{i-1}^{n} \emptyset_2\, \Delta\, lnK_{t-1} + \sum_{i-1}^{n} \beta_{2_2}\, lnK_{t-1} + \sum_{i=1}^{n} \emptyset_3 \Delta lnL_{t-1} + \sum_{i-1}^{n} \beta_3\, lnL_{t-1} + \sum_{i-1}^{n} \emptyset_4\, \Delta lnPrim_{t-1} + \sum_{i-1}^{n} \beta_4\, lnPrim_{t-1} + \sum_{i-1}^{n} \emptyset_5\, \Delta lnSec_{t-1} + \sum_{i-1}^{n} \beta_5\, lnSec_{t-1} + \sum_{i=1}^{n} \emptyset_6\, \Delta lnTer_{t-1} + \sum_{i=1}^{n} \beta_6\, lnTer_{t-1} + \varepsilon_t \ \ldots\ldots\ldots\ldots \tag{4}$$

Where β_i are the long-run regression coefficients, $\emptyset_i$ are the short-run coefficients and ε_t is the error term.

Bounds testing

A bound test was estimated using OLS to investigate the existence of a long-run relationship. The bound test applied F or T statistics testing the hypothesis below.

$$H_0: \beta_1 = \beta_2 = \cdots \beta_i \qquad (5)$$

$$H_i: \beta_1 \neq \beta_2 \neq \cdots \beta_i \qquad (6)$$

The model was subjected to misspecification tests which included normality test, serial correlation test, heteroscedasticity test to check robustness and stability and as well validate the bound test hypothesis.

In a case $H_0$was rejected, an error correction parameter would be introduced to measure the speed of adjustment towards the long-run equilibrium. The error correction term (*ECT*) is derived from the corresponding long-run model whose coefficients are obtained by normalising the equation The unclosing of an error term transforms the model into an error correction model (ECM). The advantage of the ECM model is that it integrates the short-run dynamics with the long-run equilibrium without losing long-run information. The ECM model also avoids problems of spurious relationship resulting from non-stationary time series data, that is normally experienced in linear multivariate regressions.

Therefore, the above equation is rewritten and specified as an ECM model as shown below.

$$\Delta lnY_t = \propto_0 + \sum_{i=1}^{n} \emptyset_1 \Delta lnY_{t-1} + \sum_{i=1}^{n} \beta_1 lnY_{t-1} + \sum_{i-1}^{n} \emptyset_2 \Delta lnK_{t-1} + \sum_{i-1}^{n} \beta_{2_2} lnK_{t-1} + \sum_{i=1}^{n} \emptyset_3 \Delta lnL_{t-1} + \sum_{i-1}^{n} \beta_3 lnL_{t-1} + \sum_{i-1}^{n} \emptyset_4 \Delta lnPrim_{t-1} + \sum_{i-1}^{n} \beta_4 lnPrim_{t-1} + \sum_{i-1}^{n} \emptyset_5 \Delta lnSec_{t-1} + \sum_{i-1}^{n} \beta_5 lnSec_{t-1} + \sum_{i=1}^{n} \emptyset_6 \Delta lnTer_{t-1} + \sum_{i=1}^{n} \beta_6 lnTer_{t-1} + \delta ECT_{t-1} + \varepsilon_t \ldots\ldots (7)$$

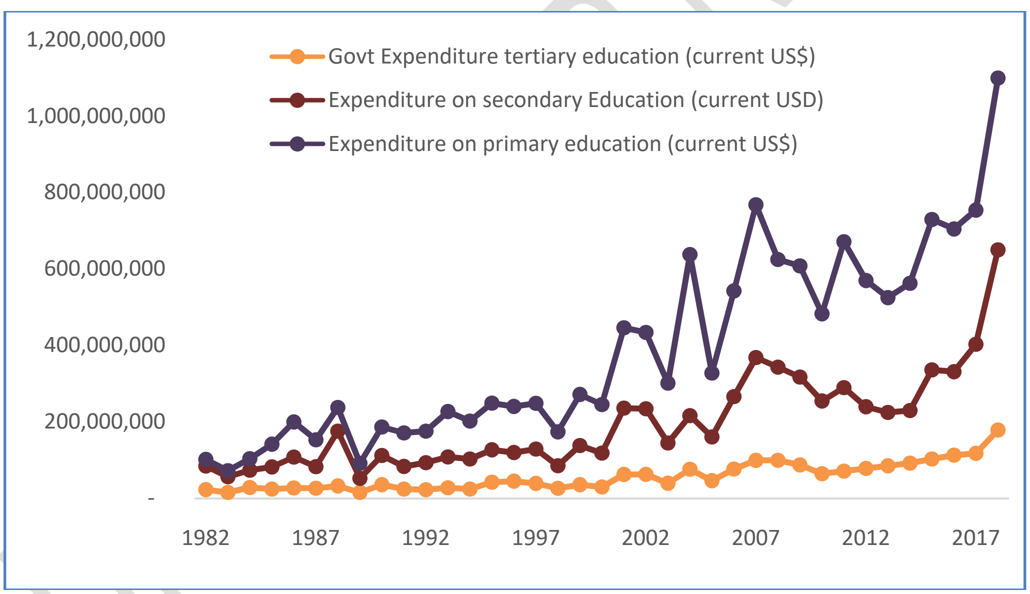
Results and discussion

Description of productivity variables

Table 1: Distribution of study variables

Variables	Obs	Mean ('000')	Std. Dev. ('000')
Dependent variable			
Agriculture Sector output (AGRI)	37	3,150,000	1,850,000
Explanatory variables			
Expenditure on tertiary education (*Tert*)	37	56,400	36,800
Expenditure on secondary education (*Sec*)	37	137,000	90,000
Expenditure on primary education (*Prim*)	37	192,000	132,000
Capital formation (*K*)	37	2,420,000	2,450,000
Employed in Agriculture Sector	37	7,140,000	1,790,000
Employed in industry Sector	37	737,000	201,000
Employed in Service Sector	37	2,200,000	583,000

Exchange rate UGX3700=1USD



Data source:World Bank Development Indicators

Fig 2: Effect of investment in education on productivity outcomes

Testing fitness and stability of model

Before running the ARDL model, the appropriate lag length was determined using three selection information criteria; namely Akaike Information Criteria (AIC). The optimal lag length structure estimates for the endogenous variables namely;

l*nY, lnPrim, lnSec, lnTert*, *lnK* and *lnL* across all information selection criteria was four as this level had the least absolute values (see Table S1). Unit root test was done to test stationarity of data, using the Augmented Dickey-Fuller unit root test methodology. The purpose was to establish whether all variables were integrated in the order I (0) or I (1) and none I (2). The results of the unit root tests of all study variables are presented in Table S2. The results indicate that the natural logs of the variables were not stationary at level apart from public investment in education (*prim*) which was stationary at I(0). Therefore, the null hypothesis was rejected on this account as the series were stationary at 1(0) after first differencing for the remaining variables. The results also show that the remaining dependent variables were not stationary in their natural logarithm or at their level form. However, after the first differencing all the variables attained stationarity with t-statistic value significant at 0.01. An indication that the series was integrated with I (1) and none were of order I(2).

Results of the bounds test are shown in Table S3. The estimates reveal that the F-statistic of 2.309 was lower than the critical value of all 1(0) regressors of 2.62 and 3.41, respectively. Similarly, the t-test statistic also estimated that the critical value was less than 1(1) regressors and greater than I(0) regressors at both 5 % and 1% significance level. This implies that the series are not cointegrated and as such, they do not exhibit long-run relationships. Therefore, accepting the H_0 hypothesis that postulates a no level relationship among the variables and hence justifying the application of the ARDL model. The model was further subjected to Breusch-Godfrey LM test for autocorrelation that confirmed the presence of serial correlation in its structure that was significant at 1%, though with a much smaller chi-squared value of 6.635. The presence of serial correlation was further confirmed by the Durbin Watson statistic of 2.653 that was higher than 1.35 and 1.05 critical values at 5% and 1% level of significance, respectively. However, as discussed earlier, serial correlation is not a problem when using ARDL modelling. The test for a linear form of heteroscedasticity was done using Cameron & Trivedi's decomposition of IM-test for unrestricted heteroskedasticity. The heteroscedasticity test had *p* values of 0.4180 that was not significant at all levels and therefore, accepting the null hypothesis that the model was homoscedastic.

ARDL Estimates of the effect of public expenditure on education on Agriculture sector growth

The ARDL model for estimating the effects of public investment in education on agriculture sector output had a lag structure of (4,4,0,2,3,3) as shown in Table 3. Under primary education, data shows that an increase in public expenditure by one unit leads to 0.9 units increase in agriculture sector output after a period of one year holding other factors constant. After two and three years, the returns to public investment in primary education declines and in the fourth year affects the sector output negatively, though with no statistical significance. Smilarly, public investment in secondary education though positive did not affect the agriculture sector output in statistically significant terms keeping other factors constant. While public expenditure on tertiary education, there were mixed results. For instance, in the first year, there are no noticeable effects on the sector output. However, after one year, a percentage increase in public expenditure on tertiary education leads to a reduction of 0.7% in the sector output and this effect was significant at 1%

confidence interval. After two years, a percentage point increase in public expenditure on tertiary education led to growth of the sector by a margin of 0.5% and the effect was significant at 1% level of significance, holding other factors constant.

Overall, public expenditure on education has a net positive effect on agriculture sector output. The impact of education on agriculture output has been proven to promote agriculture output through supporting farmer adoption of new productivity enhancing technologies. Fan and Zhang (2008) while investigating public expenditure and poverty reduction in rural Uganda, observed that whereas public expenditure on agriculture research and development was a key driver to rural poverty reduction, public expenditure on education effects ranked second. An educated farmer is more likely to adopt new and efficient means of production to maximise returns on investment consequently improving the rural well-being and status (Nchuchuwe and Adejuwon, 2012). The wellbeing is attributed to the fact the communities with higher rates of adoption of improved agricultural technologies and, consequently, higher crop yields enjoy lower food prices, higher real wages and welfare indicators (Minten and Barrett, 2008). Aura (2016) while investigating the determinants of farmer adoption of soil fertility management practices concluded that increasing literacy level supported farmers to acquire new knowledge and to calculate appropriate input quantities in a rapidly changing environment.

While investigating the nexus of education and agricultural productivity in Uganda, Appleton and Balihuta, (1996) found that primary schooling of neighboring farm workers increased productivity. The core argument was that education complements capital and substitutes for labour. Agriculture productivity increases arise through education increasing physical capital and purchased inputs. Similar evidence was also observed elsewhere. Alene and Manyong, (2007) observed that only four years of education among rural households in Nigeria raised cowpea production under improved technology by 25.6% and concluded that education has a higher payoff.

Huffman (2002) argues that with the rapid advances and fall in prices of communication and information technologies, farm people of the future will need strong basic schooling to adopt and technologies to enable them to take part meaningfully in the new global information system of the 21st century and their recent evidence that supports this argument. Luh (2017) using the switching regression model to examine the role of education on agriculture productivity in South East Asian countries, observed that for economies where agricultural productivity exhibits obvious improvements throughout the entire period, education constitutes a major determinant of the change in productivity. This result confirms the long-held view that countries in sub-Saharan Africa to effectively diversify their economies, improve productivity and build value chains for agriculture will require significant investment in human capital (Darvas *et al*., 2017; Hanushek and Wößmann, 2007). These results indicate that basic and advanced human capital has a positive impact on agriculture output and therefore a balanced educational policy that promotes basic education, as well as tertiary education, is perhaps still a viable public investment option.

In respect to physical capital accumulation, a percentage increase leads to an increase of 0.648% in agriculture sector output, which estimates are significant at a 95% confidence interval. This is attributed to flows from investments in physical capital stock that includes equipment, structures, inventories, and land that enhances agriculture output through improving the efficiency of production (Abdih and Joutz, 2006). Investments in physical capital and capacity building have been considered as the two main cornerstones of a place-based approach to rural development. Physical capital reduces costs for economic agents to access urban markets leading to higher technical knowledge and the elimination of diminishing returns (Zasada *et al*., 2015). Blundell *et al*. (1999) concluded that accumulation of physical capital is a principal factor in national economic growth. Physical capital complemented by human capital physical capital investments can be viewed as an indirect contribution of education to macroeconomic growth. Baier *et al*., (2006) made similar conclusions on the complementarity of human and physical capital while investigating the relative importance of the growth of physical and human capital on total factor productivity (TFP) using data from 145 countries that spans more than 100 years. It can as well be concluded that physical capital accumulation resulting predominantly from rural infrastructure facilities like irrigation, electricity, and roads lead to increased sector output, and this creates the rationale for such investment to spur rural growth.

While estimating the effect of the labour force on agriculture sector output, the study did not apply concepts of labour productivity which estimate the efficiency of resource use. The empirical estimate reveals that in the first two years, any increase in labour has a negative effect on agriculture sector output though not significant. However, after the second lag period, a percentage increase in labour leads to a 0.18% increase in agriculture sector output holding other factors constant, and these effects are significant at 5% level. While in the later years the effect is negative. These disparities can be attributed to labour mobility within the different sectors of the economy, with the more educated workforce moving to service and industry sectors.

Whereas agriculture indeed employs close to 70% of the labour force, most of this labour force is unskilled, produce at subsistence scale and have low marginal productivity. As such, the agriculture sector seems to benefit less from social returns to schooling (Psacharopoulos and Patrinos 2018). Alani (2018) reinforces this argument that pushing the under the skilled segment of the population into the labour market is a no-win situation, as they will remain destined for a hand-to-mouth existence based on vulnerable employment and for the economy which gains little in terms of boosting its labour productivity potential.

Table 2: ARDL Estimates of the effect of public expenditure on education on Agriculture sector growth

Dependent variable	**ARDL (4,4,0,2,3,3) regression**			
Agric Sector output	Coef.	Std.Err.	t	P>t
InAgricoutput (-1)	0.679**	0.273	2.480	0.030
InAgricoutput (-2)	0.630**	0.284	2.220	0.048
InPrim (0)	-0.159	0.206	-0.770	0.456
InPrim (-1)	0.904***	0.208	4.350	0.001
InTert (-1)	-0.746***	0.204	-3.670	0.004
InTert (-2)	0.502***	0.159	3.160	0.009
InK (0)	0.648**	0.300	2.160	0.054
InK (-1)	-0.719**	0.273	-2.630	0.023
InK (-3)	-0.559*	0.280	-2.000	0.071
InL (-2)	0.805***	0.515	3.500	0.005
InL (-3)	-0.818**	0.310	-2.640	0.023
_cons	-9.996*	5.297	-1.890	0.086
Prob > F	0.0000			
R-squared	0.9873			
Adj R-squared	0.9630			
Log likelihood	46.650353			
Root MSE	0.1019			

Robustness test of the model

The test results are shown in the figure below. The result indicated the model was structurally stable as shown by the cumulative sum of recursive residuals with most of the data points lying within the confidence interval limits at 5% threshold hence showing no evidence of the ECM's instability. There were only five occasions between the period 2003 and 2008 where the data points lied outside the limits of significance interval at the 5% threshold revealing instability of the coefficients on the test variables.

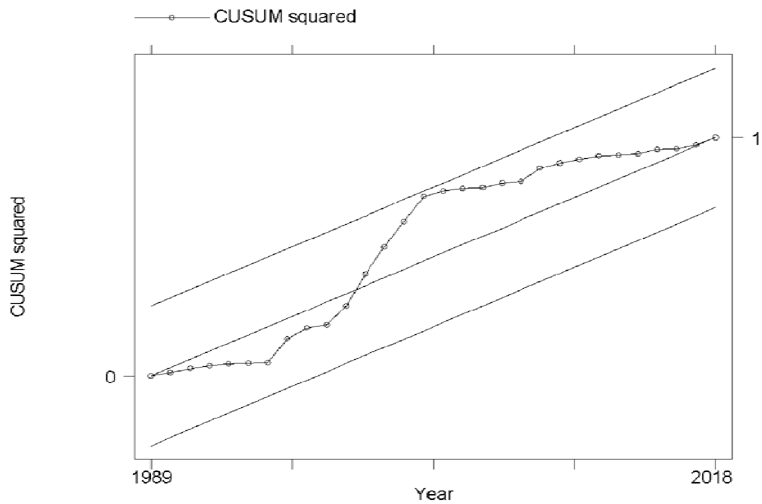


Figure 3. CUSUMSG test for lnagricout, lnPrim, lnSec lnTert lnK lnL *cs(cusum) uw(upper*

Conclusion and policy recommendations

Overall, public expenditure on education had a net positive effect on agriculture sector output. There is no doubt that growth in the sector can be stimulated from innovations emanating from the country's agricultural training and research innovation system. Even with the current raging debate between economic growth and structural change, the study confirms that it is possible to increase agriculture output and stimulate transformation of the sector through having an educated population. The study strongly recommends strengthening education investment in rural areas that have their economies driven by agriculture. This should be a vigorous effort to sufficiently equip staff rural schools and substantially improve the learning environment. At policy level, there will be a need to explore whether the current curriculum is appropriate to train and deliver high quality and skilled learners to meet the capacity needs of the agriculture sector to promote better and faster rural economic development.Based on enrolment data at tertiary education level, the study recognises that there is still a challenge of attracting students to study agriculture as a discipline. As a result, the sector has a deficit of critical mass of skilled and appropriate human capital to apply skills technology and innovation to unlock the critical value chains. Therefore, for the country to fully reap human capital dividends for the benefit of the agriculture sector, it will require a multifaceted approach with a sustained public investment, institutional reforms and policy implementation devoid of ambiguous and narrow-minded interventions such as the civil-military operation, the so-called operation wealth creation.

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S1: Information Selection criteria

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	8.65	0	-0.161	-0.07	0.112			
1	183.61	349.92	36	0	0	-8.582	-7.942	-6.68
2	230.63	94.05	36	0	0	-9.251	-8.06	-5.71
3	302.23	143.21	36	0	0	-11.408	-9.669	-6.24
4	399.96	195.45*	36	0	1.7e-13*	-15.15*	-12.86*	-8.35*

Endogenous: lnY lnPrim lnSec lnTert lnK lnL Exogenous: _cons

Table S2: Results for Unit root test

Variable	Stationarity level I (0)			Stationarity at first difference I (1)		
	t-stat	**alpha 5%**	**P Value Z (t)**	**t-stat**	**alpha 5%**	**P Value Z (t)**
GDP (Y)	1.226	-1.691	0.8857	-3.322**	-1.692	0.0011
Primary Education expenditure (prim)	-2.203*	-1.691	0.0172	-8.564**	-1.692	0.0000
Secondary Education	-1.620	-1.691	0.0573	-11.343 **	-1.692	0.0000

Expenditure (Sec)						
Tertiary Education Expenditure (Tert)	-1.314	-1.691	0.0987	-11.030**	-1.692	0.0000
Labour force (L)	0.035	-1.691	0.5139	-5.468**	-1.692	0.0000
Physical Capital (K)	-0.990	-1.691	0.1645	-5.597 **	-1.692	0.000
Service Sector Output (Serv)	-1.593	-2.969	0.4872	-3.355*	-2.972	0.0126
Industry Sector Output (Ind)	-0.853	-2.969	0.8030	-5.870**	-2.969	0.0000
Manufacturing Sector Output (Man)	-0.647	-2.969	0.8599	-4.790**	-2.972	0.0001
Agriculture Sector Output (Agric)	-1.053	-2.969	0.7334	-4.043	-2.972	0.0012

*The * and ** denote rejection of the null hypothesis at 5% and 1% respectively. All variables were converted to natural logs*

Table S3: Bound test lnagricout, lnPrim, lnSec, lnTert, lnK, lnL

Bound test	**Level 0.05**		**Level 0.01**	
	1(0)	**I(1)**	**1(0)**	**I(1)**
F stat (2.309)	2.62	3.79	3.41	4.68
T stat (1.780)	-2.86	-4.19	-3.43	-4.79
Breusch-Godfrey LM test				
Chi Squared		6.635 (0.01)		
Cameron & Trivedi's decomposition				
		Chi Squared	P	
Heteroskedasticity		33.00	0.4180	
Skewness		10.77	0.9672	
Kurtosis		3.87	0.0492	

CONSENT (WHEREEVER APPLICABLE)

No manuscripts will be peer-reviewed if a statement of patient consent is not presented during submission (wherever applicable).
This section is compulsory for medical journals. Other journals may require this section if found suitable. It should provide a statement to confirm that the patient has given their informed consent for the case report to be published. Journal editorial office may ask the copies of the consent documentation at any time.

Authors may use a form from their own institution or SDI Patient Consent Form 1.0. It is preferable that authors should send this form along with the submission. But if already not sent during submission, we may request to see a copy at any stages of pre and post publication.

If the person described in the case report has died, then consent for publication must be collected from their next of kin. If the individual described in the case report is a minor, or unable to provide consent, then consent must be sought from their parents or legal guardians.

Authors may use the following wordings for this section: "All authors declare that 'written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal."

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This section is compulsory for medical journals. Other journals may require this section if found suitable. If human subjects are involved, informed consent, protection of privacy, and other human rights are further criteria against which the manuscript will be judged. It should provide a statement to confirm that the authors have obtained all necessary ethical approval from suitable Institutional or State or National or International Committee. This confirms either that this study is not against the public interest, or that the release of information is allowed by legislation.

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