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MAKERERE UNIVERSITY

DETERMINANTS OF AGRICULTURAL PRODUCTIVITY IN UGANDA

BY

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A RESEARCH PAPER SUBMITTED TO THE DIRECTORATE OF RESEARCH AND GRADUATE TRAINING IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ARTS IN ECONOMIC POLICY AND PLANNING OF MAKERERE UNIVERSITY

JANUARY, 2021

DECLARATION

DECLARATION

I, Prossy Nakalule, affirm that this work is original and has not been submitted for any academic award to any University or institution of higher learning.

Sign: ......Prossie.......... Date: ...22-01-2021...

Prossy Nakalule

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APPROVAL

APPROVAL

This research paper has been submitted for examination with the approval of the following University Supervisor.

Sign: .... Date: 27/01/2021

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DEDICATION

This Research paper is dedicated to my most beautiful daughter and son. Thank you for giving me a purposeful life.

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I would like to thank the Almighty God for the life, support and wisdom. I take the pleasure to acknowledge the advice, support and encouragement extended to me at various stages.

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My sincere thanks also go to all lecturers at School of Economics, Makerere University and fellow students' of 2017 cohort especially my group discussion members for the valuable contribution offered throughout the program. Last but not least, to my parents, husband, sisters, brothers and work mates for their heartfelt support and encouragement.

TABLE OF CONTENTS

ABSTRACT

This study investigated determinants of agricultural productivity in Uganda using quarterly data for the period 2007 to 2017. Descriptive statistical and econometric methodologies were utilized to analyze the data. The variables that were considered consisted of agricultural productivity, expenditure on capital (including on-farm irrigation and infrastructure), research and development investments in agricultural research, expenditure on extension services and population growth rate. According to the regression results, the determinants of agricultural productivity in Uganda at 5 percent level are; research and development investments in agricultural research, expenditure on extension services and population growth. The study recommends increased investment in Uganda's agriculture research and development since these are key sources of agriculture productivity growth since this can change the production process by applying innovation, newly achieved scientific and practical knowledge and through management skills.

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADF	Augmented Dickey Fuller
ECGF	Export Credit Guarantee Fund
ECM	Error Correction Model
FAO	Food Agricultural Organisation
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GHI	Global Harvest Initiative
MoFPED	Ministry of Finance, Planning and Economic Development
NDP	National Development Plan
RER	Real Exchange Rate
RGDP	Real Gross Domestic Product
UBOS	Uganda Bureau of Statistics
VAR	Vector Autoregressive
VECM	Vector Error Correction Model

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Improving agricultural productivity has been the world's primary means of assuring that the needs of a growing population do not outstrip the ability to supply food. Productivity measures the efficiency with which inputs are transformed into outputs in a given economy (Li & Prescott, 2009; Shittu & Odine, 2014). Hunger, food insecurity, and malnutrition pose major health and economic challenges in the Uganda (Diiro, 2017). As a result, raising agricultural productivity has been Uganda's development agenda for long, though success has been quite low (Nabbumba & Bihiigwa, 2003).

Global Harvest Initiative (GHI) revealed that global agricultural productivity growth is not accelerating fast enough to sustainably feed the world because of stagnant or slowing agricultural productivity in many countries (GHI, 2015). This is particularly the case in many developing economies that relied largely on land expansion to drive agricultural growth. Given that land is a scarce resource, expansion of more cultivated area is not possible in many developing countries (Mozumdar, 2012). Therefore, factors other than land should be employed to solve the problem of low agricultural productivity in the nexus of an increasing population that can impede food security.

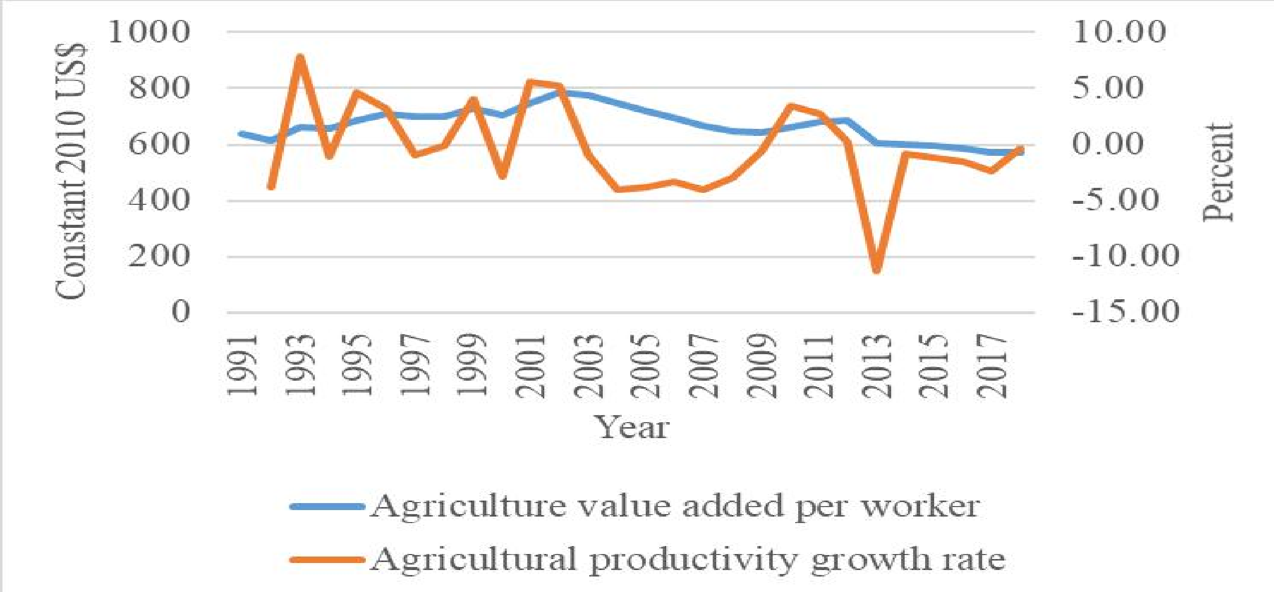
According to FAO (FAO, 2013), in the 1960s, agricultural productivity thrived in Uganda due to both area expansion and yield improvements: food production increased more than population. Since the 1970's, this trend changed, agricultural productivity decreased (FAO, 2013) and there is no clear explanation about stagnation of productivity in Uganda. Hasan and Quibriam (2004) and World Bank (2008) indicate that improving agricultural productivity plays a key role in achieving food security and in reducing poverty globally. The World Bank (2008) argued that achieving high agricultural productivity requires investment in education especially of women, improvement of rural infrastructure including roads, water sources, communication and markets;

and that these must be complemented by private investment in inputs such as fertilizers, farm machines, and vehicles.

In addition, the World Bank (2008) upholds the view that public investment in the form of human capital such as education, extension and training lead to increase in agricultural productivity. Although some measures of agricultural productivity incorporate inputs and physical capital, leaving human and social capital, technology, institutions, infrastructure and policy to explain growth in agricultural productivity, the omitted factors determine the efficiency of use of inputs and physical capital. The quality of human capital determines whether and how technology will be adopted; technology choice determines the inputs and physical capital to be used. Thus, to achieve agriculture productivity growth and resilience in Uganda will require better technology, tenure security and sound land management practices, as well as the dissemination of knowledge on sustainable input use through effective extension services (World Bank, 2018). Further still, boosting the sector needs higher-value addition and job creation, policy implementation and regulation to be strengthened; institutional coordination improved; and private sector participation encouraged. Also, the organization of producers and their integration into sustainable agri-food value chains should be supported to increase farmers' access to finance and markets, and for the competitiveness of the sector more broadly (World Bank, 2018).

Available data on Uganda's agricultural productivity (proxied by annual average agriculture value added per worker) show that during the period 1991-2018, agricultural productivity teetered between 570 US dollars and 784 US dollars as in Figure 1.1 and averaged at 670.46 US dollars for the same period. It hit an all-time low in 2018 to stand at 570 due to weather conditions, while it stood at an all-time high of 784 in 2002. Agriculture value added per worker of Uganda fell gradually from 727 US dollars in 1999 to 570 US dollars in 2018. Thus, according to United Nations Conference on Trade and Development (2015), low productivity in agriculture is a major reason for the prevalence and persistence of poverty in most LDCs (Uganda inclusive), keeping much of the rural population trapped in a vicious circle of poverty which results in undernutrition, poor health, poor cognitive development and limited adoption of new technologies, which in turn lead to low productivity and low earnings.

Figure 1.1: Trend of agriculture value added per worker and its growth (1991 to 2018)



Source: UBOS

1.2 Problem Statement

Despite several attempts to raise agricultural productivity in Uganda, success has been significantly low. The modest increases in productivity since 1990 are attributed to expansion of cultivated land rather than improvement in productivity per unit area of land (World Bank, 2008). Nabbumba and Bahiigwa (2003) observed that expansion of cultivated land is becoming unsustainable since access to land is increasingly constrained by the high population growth.

Furthermore, very scanty literature is available to explain how agricultural productivity should be enhanced in Uganda (Chauvin et al., 2012; Fuglie & Rada, 2013). It was against this background that this study empirically investigated the determinants of agricultural productivity in Uganda.

1.3 Objectives of the Study

The major objective of the study was to establish the determinants of agricultural productivity in Uganda.

The specific objectives were to:

1. Examine the relationship between agricultural extension/technology transfer and agricultural productivity.
2. Investigate the relationship between agriculture expenditure on capital (including on-farm irrigation and infrastructure) and agricultural productivity.
3. Examine the relationship between research and development investments in agricultural research and agricultural productivity.

1.4 Hypotheses

The following hypotheses were tested in this study:

1. There is no significant relationship between agricultural extension/technology transfer and agricultural productivity.
2. There is no significant relationship between agriculture expenditure on capital (including on-farm irrigation and infrastructure) and agricultural productivity.
3. There is no significant relationship between research and development investments in agricultural research and agricultural productivity.

1.5 Scope of the study

The study assessed determinants of Uganda's agricultural productivity using available quarterly secondary data covering a period of 11 years that is 2007 – 2017 (inclusive).

1.6 Significance of the study

The study might provide an understanding on the determinants of agricultural productivity in Uganda particularly, agriculture expenditure on capital (including on-farm irrigation and infrastructure), irrigation infrastructure and other agricultural infrastructures other than roads or irrigation), research and development investments in agricultural research, agricultural extension/technology transfer and population growth rate which information is used by researchers, consultants and academicians.

The study might be of help to the advocates and policy makers of the agricultural sector who use it to lobby from government (both local and central), development partners and donors; for more resources to help eliminate constraints within in the sector. This might also help come up with capacity building mechanisms to help farmers overcome the barriers that impede agricultural productivity.

1.7 Structure of the research paper

This research paper is made up of five chapters. Chapter one includes background to the study, statement of the problem, objectives of the study, research hypotheses, scope of the study and significance of the study. The literature related to this study is stated in chapter two while chapter three presents the data sources, model specification and estimation procedure and robustness checks. In chapter four, study findings are presented and discussed. Finally, chapter five presents summary of the findings, conclusions, recommendations and areas for future research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter is designed to provide a review of existing literature for explaining the agricultural productivity. It provides the theoretical framework and empirical literature. The review also covers theoretical literatures by other writers in relation to agricultural productivity.

2.2 Productivity measures in agriculture

Agricultural productivity is the measurement of the quantity of agricultural output produced for a given quantity of input or a set of inputs. There are different ways of defining and measuring productivity. For instances, the amount of output per unit of input (such as tons of wheat per acre of land), or an index of numerous outputs divided by an index of numerous inputs (Wiebe, 2003). The quantities of output relative to the quantity of inputs are the conventional measures of productivity. If output increases at the same rate as inputs, then productivity is unchanged. On the other hand, if the output growth rate exceeds the growth rate in the use of inputs, then productivity is positive.

Two measures are often used. First, partial factor productivity measure, state the amount of output per unit of a particular input like land or labour, and the second total factor productivity measure. Most commonly used partial measures are land productivity, i.e., yield or output per unit of land, and labour productivity i.e., output per economically active person (EAP) or per agricultural person-hour (Zepeda, 2001). Sometimes the indication from partial measures of productivity is not clear enough to show why production is changing. This is because different factors are responsible for changing the productivity, for example, land or labour productivity can increase due to better and more use of fertilizer, power tillers, and the use of high yielding variety (HYV) etc. To avoid such kinds of problems, it is better to measure total factor productivity (TFP) to account for the accurate agricultural productivity. Hence, the measure of multifactor or total factor productivity indicates total output relative to a more comprehensive metric of all measurable inputs including land, labour, capital, livestock, chemical fertilizers, pesticides and other purchased inputs (Alston et al., 2009).

It is worthwhile to note that different productivity measures are used for different purposes. For example, yield or land productivity is usually used to evaluate the success of new technology. It is also useful to determine what amount of land is required to meet the future demands of world food (Wiebe, 2003). Labour productivity is usually used for comparing productivity among sectors within or across economies (Block, 1994). It also facilitates to determine the incomes and wellbeing of people engaged in agriculture (Wiebe, 2003). The growth in TFP is usually a measure of technological advancement that can be ascribed by the development of scientific agricultural research, enhancing extension services, human capital development such as education and the development of infrastructure and government policies (Ahearn et al., 1998).

2.3 Theoretical model

The model used is the Cobb-Douglas Production Function. To establish the individual or joint contribution of inputs to output it is necessary to establish a production function. The general neoclassical production function: $Y = F(X_1, X_2, X_3, \dots \dots, X_n)$ or $Y = AK^{\alpha} L^{\beta}$ where Y is the output level, Xs are the inputs; A, α & β are positive constants; K & L are capital and labour input respectively. A is the total factor productivity, α & β are capital and labour elasticities respectively. The factors are constant and determined by the available technology (Koutsoyiannis, 2006).

The Cobb-Douglas production function is of degree one if $\alpha + \beta = 1$. A production function of degree one has constant returns to scale. If $\alpha + \beta < 1$ then the production function exhibits decreasing returns to scale. If $\alpha + \beta > 1$ the production function exhibits increasing returns to scale. The value of α and β determine what degree of returns to scale a Cobb-Douglas production function can exhibit. Since the values of α and β are not limited, Cobb-Douglas production function can exhibit any degree of returns to scale (Koutsoyiannis, 2006).

To eliminate the bias in Cobb-Douglas production function, the equation can be transformed by taking the logarithms of both sides. Comparing the transcendental logarithmic function (trans-log) and Cobb-Douglas production function, the former is relatively more flexible, thus it is more appropriate especially when estimating a production relationship which is not well understood.

This transformed function can be estimated through ordinary least square technique (OLS). Thus, the Cobb-Douglas production function can be written as $\ln Y = \ln A + \alpha \ln K + \beta \ln L$. Ordinary least square (OLS) can be used to estimate the model as it is now linear in parameters. With all the variables in logs, this is now a log-linear model.

Generally, Cobb-Douglas production function can be generalized to many inputs to take the following function; $Q = \prod_i^n = 1 \prod_i^{\beta_i}$. This function can exhibit any degree to scale depending on the value of summation of βi. In this study, the Xs are agricultural extension services, agricultural infrastructure, research and development investments in agricultural research and population growth rate.

The logical basis for choosing Cobb-Douglas production function is based on the fact that it is relatively simple and convenient to specify and interpret. Moreover, application of Cobb-Douglas production function has been found applicable in similar settings to this one. For instance, (Enu & Attah-Obeng, 2013) and (Ekborn, 1998).

2.4 Empirical literature

Majority of the researchers have given attention to the function of conventional inputs like land, labour, water, chemical fertilizers and physical capital etc. in explaining the productivity growth (Lachaal, 1994). Along with the above factors, the role of human capital, research and technological development or technology transfer, public investment in agricultural research, extension services and infrastructural development etc. are also important strategies and closely linked to agricultural productivity (Auraujo et al., 1997).

2.4.1 Population growth

In a study on the determinants of agricultural productivity in Kenya, Muraya and Ruigu (2017) found that there is a negative impact of exchange rate and inflation on agricultural productivity whereas labour force in terms of population growth, rainfall, and government expenditure has a positive impact on agricultural productivity in the long run. In the short run population growth, rainfall, and government expenditure are the main determinants of agricultural productivity. In this study, it has been found that population growth rate is also a significant determinant of agricultural productivity in Uganda.

Anyanwu (2013), carried out a study on agricultural productivity determinants in Nigeria. He formulated an econometric model to analyze his data as follows:

Q = F (X_1, X_2, X_3……X_{12}, e); where, Q is the aggregate agricultural productivity and X_1, X_2, X_3, TO, X_{12} are farm size, labour input in terms of population growth, expenditure on planting material, non-farm income, capital input, expenditure of fertilizer, number of crops in the mixture, distance to the market, level of education of the farmer, age of the farmer, size of households, experience of the farmer and e is the error term. That study found farm size, labour input in terms of population growth, expenditure on planting material, non-farm income, capital input, the number of crops in the mixture, distance to the market, the level of education of the farmer, experience of the farmer were statistically significant determinants of aggregate agricultural output. This study was done on firm level but the current study focussed on the macroeconomic determinants of agricultural productivity in which population growth has been found to significantly determine agricultural productivity in Uganda.

Enu & Attah-Obeng (2013) set out to establish the macro determinants of agricultural productivity in Ghana for the period 1980 to 2011. The study used a Cobb-Douglas production function and ordinary least squares estimation technique to analyze the data. Agricultural output was the dependent variable. Labour force proxied by population growth, real GDP per capita, inflation, and real exchange rate were the independent variables. The study found that apart from inflation all the other factors that is population growth, inflation, real exchange rate, real GDP per capital, were significant in determining agricultural productivity. The results of this study particularly population growth rate are in agreement with the findings of Enu & Attah-Obeng (2013).

Hussain and Ishfaq (1997) employed OLS method using annual time series data over the period 1968-96 to estimate the impact of various factors on agriculture productivity through extended Cobb-Douglas production function. The independent variables were cropped area, labour force, fertilizer, irrigation, total tractors supplied and total credit disbursed. All the variables were measured in growth form. The results of estimation revealed cropped area and fertilizer off-take as the only significant determinants of agriculture growth with elasticity coefficients of 0.66 and 0.43 percent, respectively. The findings of this study are in disagreement with the findings of Hussain and Ishfaq (1997).

Thus, majority of the researchers have given attention to the function of conventional inputs like land, labour, water, chemical fertilizers and physical capital etc. in explaining the productivity growth (Lachaal, 1994). Along with the above factors, the role of research and technological development or technology transfer, public investment in agricultural research, extension services and infrastructural development etc. are also important strategies which are closely linked to agricultural productivity (Auraujo et al., 1997). Chavas (2001) finds a weak connection between technological change and agricultural productivity growth across countries over time, which is a quite surprising finding, because there is a good deal of evidence for technological progress to contribute to strong productivity growth in agriculture over the last few decades. Green revolution in Asia is the example of that, though it has some negative aspects like environmental degradation. Thus, some of these important determinants of agricultural productivity that this study focused are also highlighted below:

2.4.2 Agricultural research, extension and technology transfer

Recent studies have found a close correlation between investment in public R&D and agricultural productivity. Studies such as Alston et al., (2011), Fuglie and Toole (2014) and Wang et al., (2013) provide evidence that R&D investments in agricultural research provide new knowledge and technologies that fuel improvements in agricultural productivity in US agriculture. Wang et al., (2013) has shown that R&D affects agricultural productivity only over the long-term. Changes in public R&D stocks have a significant impact on agricultural TFP growth. This study also shows evidence that even in developing countries, investment in agricultural research and development also plays a key role on agricultural productivity.

Similar evidence is also found for developing countries. For example, a study by Rahman and Salim (2013) in Bangladesh shows that R&D investment is one of the significant aspects that favourably affect TFP growth. Furthermore, Voutsinas and Tsamadies (2014) have found that

R&D expenditure in Greek agriculture improves the rate of technological innovation, which affects long-run productivity growth. In addition, Farid and Ruhul (2015) investigated the effects of R&D on Agricultural Productivity of Australian Broadacre Agriculture: A Semiparametric Smooth Coefficient Approach was used. The empirical results show that once both the direct and indirect effects are taken into consideration, R&D investments significantly increase agricultural productivity. The results of this study are in agreement with the findings of this study.

In addition, a number of studies also found that extension has contributed to increased agricultural productivity and farm income (Huffman, 1976; Owens, Hoddinott and Kinsey, 2003). Some of the researches measured the impact of extension service by containing extension variables, such as number of extension visits and total hours of extension worker time on crop yield per hectare and reported that extension contacts significantly increased the crop production and the value of crop production (Jamison and Lau, 1982; Jamison and Moock, 1984; Evenson, Pray and Rosegrant, 1998). However, other studies argue that agricultural extension has limited impacts on farm income and in dealing with agricultural productivity in many African countries (Gautam, 2000; Birkhaeuser, Evenson and Feder, 1991). In other words, the effect of extension services in developing countries has been still weakly functioning. But in this study, extension services have been found to determine agricultural productivity significantly.

Furthermore, Kien, Alexander and Stavroula (2016) examined what evidence says about agricultural productivity. Results from the review imply that different estimation methods, measures of variables, and model specifications affect the estimation of productivity growth and its determinants. The review also revealed that Research and Development (R&D) and technological progress have been identified as the most important determinant of agricultural productivity growth. However, agricultural research funding has been declining. Finally, the difference in productivity growth among countries could be explained by difference in resource endowment, R&D and the resulting technological progress, and the accumulation of human capital. Hence, increasing funding for agricultural research that increases technical progress should be an essential part of the overall agriculture policies as it could improve agricultural productivity growth significantly. This is in line with what this study recommended.

2.4.3 Public investment and policy

Public investment in research contributes more than half and extension provides one third of the total output growth in India (Evenson and McKinsey, 1991). One fifth of total production growth in Chinese agriculture during 1965 to 1994 was achieved by public research expenditure and the rapid growth of Chinese economy from 1980 to 1990 resulted from the government investment in research and development (Fan, 1996). Similarly, public infrastructure as well as infrastructural development may increase the productivity by promoting the exchange of goods and services. Gilberto (2012) assessed the impact of infrastructure on agricultural productivity in Philippine. The empirical results indicated a significant link between rural infrastructure and agricultural productivity where electricity and roads are significant determinants of agricultural productivity. Rural roads provide the important connectivity with growing markets adjacent to rural areas; they also lessen input costs and transaction costs of rural producers and consumers while access to electricity creates various income earning opportunities for rural households. In this study, it has been found out that Uganda's agricultural infrastructure ((that includes; off-farm collective infrastructure (roads mainly dedicated to agricultural activity, irrigation infrastructure and other agricultural infrastructures other than roads or irrigation)) does not determine agricultural productivity in the country.

Benin et al., (2009), carried out a study on agricultural productivity and public expenditure in Ghana. The results from the different zones differed marginally. The study used household production data and public expenditure data. From the study, health, education, roads and supply of public goods and services in relation to agriculture had a significant impact on agricultural productivity. From the study, a unit increase in agricultural public spending resulted in a 0.15 percent increase in agricultural labour productivity. The benefit-cost ratio of public spending on agriculture was 16.8. Spending on rural feeder roads followed with a benefit-cost ratio of 5. Health followed at a distant third. Though this study used micro data, it sheds light on how agriculture expenditure on capital (including on-farm irrigation and infrastructure) contribute to agricultural productivity.

2.5 Summary

From the above literature, some studies have employed Cobb-Douglas production function with agricultural productivity as the dependent variables while the independent variables varied in different studies with the major ones being; agricultural extension services, agriculture expenditure on capital, investment in research and development, real GDP per capita, consumer price index, farm size, human capital, fertilizer, climate change, distance to the market, and off farm non-agricultural income. Variables such as; farm size, fertilizer, distance to the market, and off farm non-agricultural income are firm level variables which the research is unable to get and use. Therefore, this study examined determinants of agricultural productivity in Uganda by making use of variables such as; agricultural extension services, agriculture expenditure on capital (including on-farm irrigation and infrastructure), investment in research and development and population growth as the independent variables.

Research gap

According to Vision 2040, productivity is still a cardinal challenge in the agricultural sector and since the sector continues to be very significant for the Ugandan economy, there is need for vigorous and extensive research so as to provide updated data to enable the relevant authorities to formulate policies and programmes which are up to date and relevant to the current trends. This study, therefore, might serve the purpose of expanding the body of literature available to enable policy makers to formulate relevant policies.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter describes the methodology that was used to achieve the stated objectives. It explains the sources of data, its coverage and the number of data points for the study. It also describes the modelling process and the tests that were undertaken to assess the determinants of agricultural productivity in Uganda.

3.2 Data sources

This study used quarterly secondary data covering a period of 11 years that is 2007 to 2017 (inclusive) hence 44 data points. Data available on agricultural extension services, agricultural capital, research and development investments in agricultural research was from 2007 to 2017 while data on agricultural value added per worker and population growth rate was from 1960 to 2019. Thus, the researcher used the period 2007 to 2017 since this covered all the variables studied. The data were obtained from Uganda Bureau of Statistics and Food and Agriculture Organisation (FAO).

3.3 Definition of variables

Agricultural productivity (AGVA) proxied by agriculture value added per worker is a measure of agricultural productivity. Value added in agriculture measures the output of the agricultural sector less the value of intermediate inputs.

Agricultural capital (AI). This was proxied by expenditure on capital (including on-farm irrigation and infrastructure). Thus, Expenditure on capital (including on-farm irrigation and infrastructure) (EC) are monetary transfers reducing the on-farm investment cost of on-farm capital (buildings, machinery and equipment, on-farm irrigation, other basic on-farm infrastructure). A positive relationship is expected between expenditure capital and agricultural productivity.

Research and development investments in agricultural research (IRD). This was proxied by expenditure on agricultural research. Expenditure on agriculture research are public expenditures financing research activities improving agricultural production. A positive relationship is expected between Expenditure on agriculture research and agricultural productivity since according to Antle and Capalbo, (1988), investment in research and development is most essential for increasing productivity.

Expenditure on extension/technology transfer (EXT) are public expenditures financing provision of extension services. A positive relationship is expected between Expenditure on extension/technology and agricultural productivity.

Population growth rate (POPGR). This refers to the change in population over a unit time period, often expressed as a percentage of the number of individuals in the population at the beginning of that period. A positive relationship is expected between population growth rate and agricultural productivity.

3.4 Estimation procedure

Data was processed and analysed using E-views software.

3.4.1 Stationarity test

The stationarity of the data was checked by using the Augmented Dickey Fuller (ADF) unit root test. The ADF specification is of the form:

$$\Delta Z_t = C_0 + C_2 t + \gamma Z_{t-1} + \sum_{i=1}^{\rho} \delta_i + \varepsilon_i \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

Where, C_0 is the intercept term, C_2 and ɣ are coefficients of time trend and level of lagged dependent variable respectively, is the first difference operator and ε_t are white noise residuals.
ρ is the lag- length introduced to account for autocorrelation, which was chosen using the minimum of the information criteria. The null hypothesis was that there was a unit root. The null hypothesis was rejected when the absolute value of ADF test statistic exceeded the critical value at 5%.

3.4.2 Diagnostic tests

Diagnostic tests were performed because before running the model; - data must be normally distributed, free from autocorrelation and heteroscedasticity. The study tested normality of the residuals using Jarque-Bera, autocorrelation was tested using Breusch-Godfrey Lagrange Multiplier test, and heteroscedasticity was tested using Breusch-Pagan Lagrange Multiplier test.

3.5 The long run model

The study employed a time series regression analysis. It derived guidance from the study done by Muraya (2017) on determinants of agricultural productivity in Kenya. This study therefore used the following model;

$$AGVA = f\left(EXT, AI, IRD, POPGR\right) \qquad 3.2$$

Where, AGVA represented agricultural productivity (proxied by agriculture value added), EXT represented agricultural extension services proxied by expenditure on extension services, AI represented agricultural capital proxied by expenditure on capital (including on-farm irrigation and infrastructure), IRD represented research and development investments in agricultural research proxied by expenditure on agricultural research, POPGR represented population growth rate.

Thus, agricultural productivity was a function of agricultural extension services, agricultural capital, research and development investments in agricultural research and population growth rate. Expressed in specific form, the above general formulation can be expressed as:

$$AGVA_t = e^{\beta_0} EXT_t^{\beta_1} AI_t^{\beta_2} IRD_t^{\beta_3} POPGR_t^{\beta_4} e^{\varepsilon_t} \qquad 3.3$$

The standard specification which summarizes the elasticity between these variables is given as:

$$LAGVA_t = \beta_0 + \beta_1 LEXT_t + \beta_2 LAI_t + \beta_3 LIRD_t + \beta_4 LPOPGR_t + \varepsilon_t \qquad 3.4$$

Where, *L* stands for natural logarithm, *LAGVA* is the natural logarithm of agricultural productivity and *ε* is the stochastic term for the period t. β's are parameters to be estimated.

3.6 Pre-estimation tests and residual diagnostics

Pre-estimation test that is normality test of variables was conducted to establish whether transformation of the variables was necessary.

To assess the goodness of fit of the model, a number of tests were applied to ensure that the findings adequately represent the data. The tests included but not limited to; Jarque-Bera for normality of the residuals, Breusch-Godfrey Lagrange Multiplier for serial correlation and Breusch-Pagan Lagrange Multiplier test for heteroscedasticity.

CHAPTER FOUR

THE DETERMINANTS OF AGRICULTURAL PRODUCTIVITY IN UGANDA

4.1 Introduction

This chapter presents the distributive properties and the transformations undertaken on the variables under study. The long run model results are also presented and discussed. In addition, the results for the necessary diagnostic tests of the model are presented and discussed.

4.2 Empirical findings

4.2.1 Graphical representation of the variables in raw form

The graphical analyses of the variables used in the study at level are presented in Figures 4.1 to 4.5. The variables are agricultural productivity, agricultural capital, research and development investments in agricultural research, expenditure on extension services, and population growth rate.

Figure 4.1: Plot of Agricultural productivity

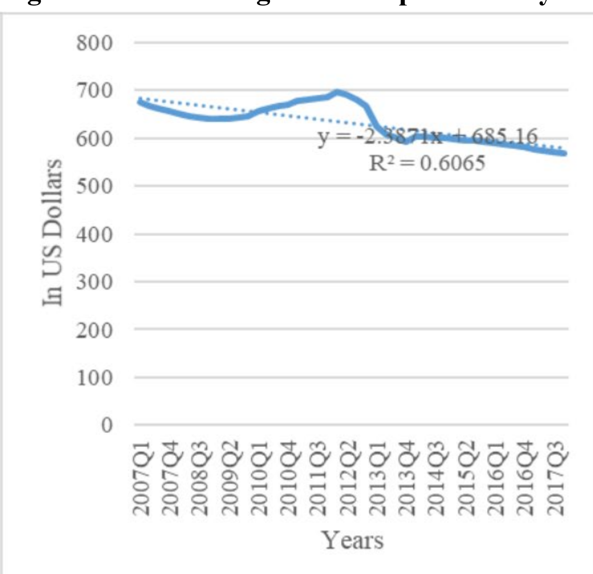


Figure 4.2: Plot of agriculture expenditure on capital

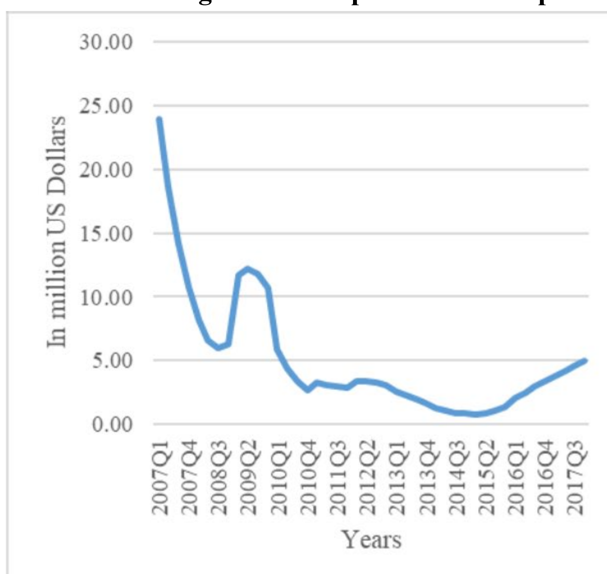


Figure 4.3: Plot of research and development investments in agricultural research

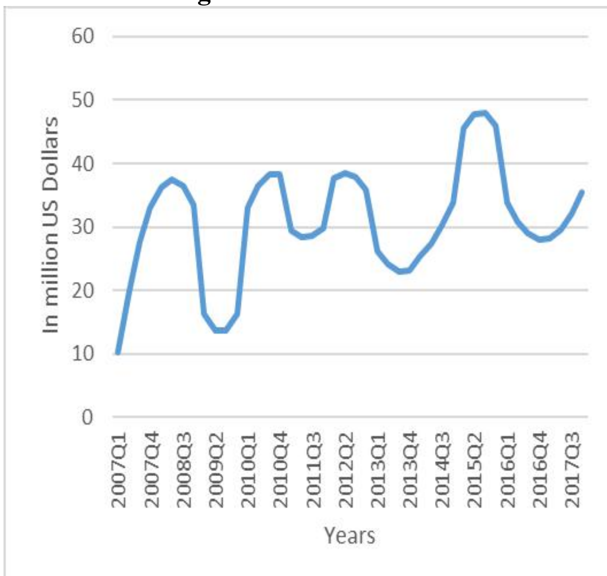


Figure 4.4: Plot of expenditure on extension services

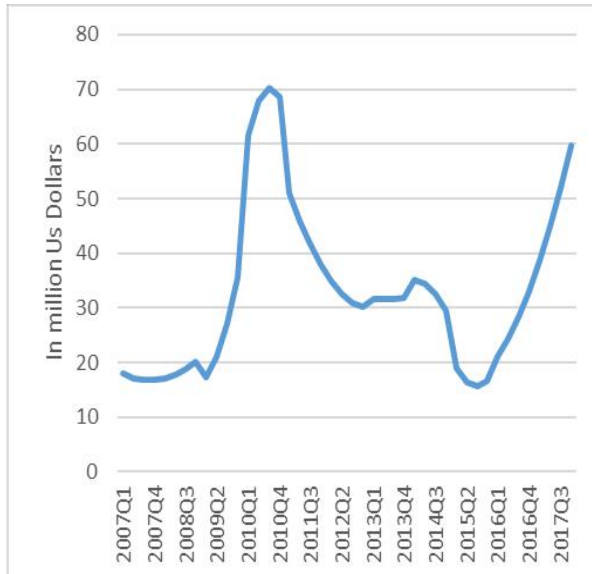
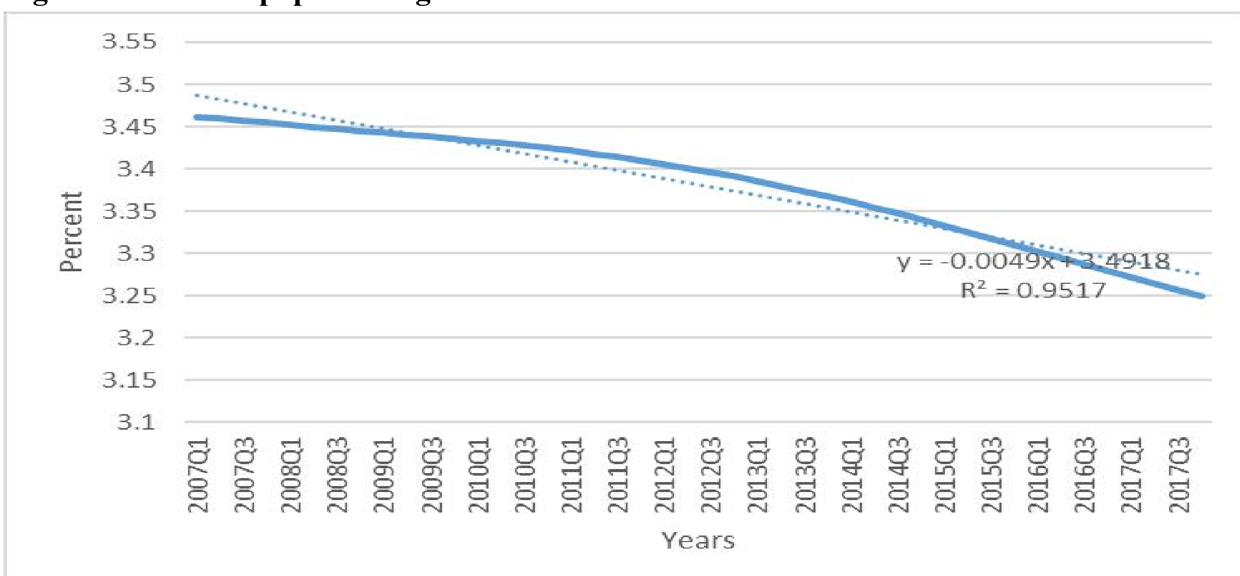


Figure 4.5: Plot of population growth



From the graphical representation in Figure 4.1, there was evident decreasing trend in the agricultural productivity. Thus, Uganda's agricultural productivity proxied by agricultural value added per worker for the period 2007 to 2017 averaged at 631.454 US dollars with a minimum value of 569.38 Us dollars in the fourth quarter of 2017 and an all-time high of 695.594 US dollars in the first quarter of 2012.

Agricultural capital (that includes; off-farm collective infrastructure (roads mainly dedicated to agricultural activity, irrigation infrastructure and other agricultural infrastructures other than roads or irrigation) equally had decreasing trend as shown in Figure 4.2. It averaged at 5.17 million US dollars from 2007 until 2017, reaching an all-time high of 23.93 million US dollars in the first quarter of 2007 and a record low of 0.74 million US dollars in the last quarter of 2015. Construction of roads is extremely important for increasing market access of crop and livestock products produced by farmers. The construction of feeder roads has improved road connectivity in rural areas, increasing chances of farmers to market their produce. The limiting factor with crop and livestock production is the dependence on rain-fed agriculture. The expenditure on water and sanitation does no target water for agricultural production which is the missing link. According to the Development Strategy and Investment Plan (DSIP, government emphasis has been on construction of markets in rural areas and construction of feeder roads to improve access. There is thus need to increase expenditure in this area.

More so, in the period 2007-2017, research and development investments in agricultural research exhibited an increasing trend with an average of 30.79 million US dollars, reaching a record high of 47.99 million US dollars in the third quarter of 2015 and a record low of 10.3 million US dollars in the first quarter of the year 2007 as shown in Figure 4.3. The increase in allocation to agriculture research is explained by the start in the operationalization and implementation of the ATAAS programme by NARO whose emphasis is to develop technologies for farmer uptake to increase productivity and to provide agribusiness advisory services. This was done to create the needed interface between agricultural research by NARO and agricultural advisory (extension) services via NAADS.

In addition, in Figure 4.4, expenditure on extension services is seen to have an increasing trend with an average of 32.82 million US dollars, it was highest in the third quarter of 2010 hitting a record high of 70.31 million US dollars and was lowest in the third quarter of 2015 reaching a record low of 15.68 million US dollars. Furthermore, Figure 4.5 shows that Uganda's population growth rate in the same period exhibited a gentle decreasing trend averaging at 3.38 percent, with a record high of 3.46 percent in the first quarter of 2007 and a record low of 3.25 percent in the fourth quarter of 2017.

4.2.2 Normality test of the variables

Jarque-Bera test of all the variables was first conducted to establish the normality of the variables and the results are presented in Table 4.1.

Table 4.1: Normality tests of variables in level

Category	AGVA in US dollars	AI in million US dollars	IRD in million US dollars	EXT in million US dollars	POPGR in percent
Std. Dev.	39.37	4999623.0	8822535.0	15367233.0	0.06
Jarque-Bera	3.76	51.47	0.51	7.11	4.08
Probability	0.15	0.00	0.78	0.03	0.13
Observations	44	44	44	44	44

AGVA represents agricultural productivity, AI represents agricultural capital, IRD represents research and development investments in agricultural research, EXT represents expenditure on extension services, and POPGR represents population growth rate.

From the results, all variables except agricultural capital and expenditure on extension services followed a normal distribution since their p-values were greater than 0.05. According to Maddala (1992), if variables are not normally distributed, one can consider transformation of variables or to increase the sample size. Therefore, variables were transformed using natural logarithms so that normality of all the variables could be achieved.

The transformation using natural logarithms was done on all the variables and the results are presented in Table 4.2. The results indicate that the transformation of the variables reduced the standard deviations and the normality of the data series improved. Hence the variables were used for further analysis in their natural logarithms.

Table 4.2: Descriptive Statistics in natural logarithms

Category	LAGVA	LAI	LIRD	LEXT	LPOPGR
Std. Dev.	0.06	0.87	0.34	0.45	0.02
Jarque-Bera	3.80	0.70	13.94	1.97	4.15
Probability	0.15	0.71	0.00	0.37	0.13
Observations	44	44	44	44	44

L stands for Natural logarithm.

4.2.3 Optimal Lag length determination

The choice of the lag length was determined on the minimum number of lags that met the crucial assumption of time independence of residuals, based on the Langrage Multiplier test (Maddala, 1992). The optimal lag length ρ was determined using the Akaike Information Criterion (AIC), Hannan and Quinn Information Criteria (HQIC) and Schwartz Bayesian Information Criterion (SBIC). Table 4.3 presents the optimal lag length using AIC, HQIC and SBIC.

Table 4.3: Lags to estimate

Lag	AIC	SBIC	HQ
0	-5.962	-5.753	-5.886
1	-25.926	-24.672	-25.469
2	-27.701*	-25.403*	-26.864*
3	-27.327	-23.984	-26.109

* indicates lag order selected by the criterion (each test at 5% level)
AIC: Akaike information criterion SBIC: Schwarz Bayesian information criterion
HQ: Hannan-Quinn information criterion

From Table 4.3, the maximum lag length is 2 and the Schwarz Bayesian information criterion was used for the selection of the optimal lag length. This was chosen due to the fact that its value was less than both the Akaike information criterion and Hannan-Quinn information criteria values in absolute terms respectively.

4.2.3 Unit root test or order of integration

When the time series are non-stationary, the regression results obtained in a traditional way are spurious (Gujarati, 2004). Thus, unit root tests were conducted on all the variables that is, agricultural productivity, agricultural capital, research and development investments in agricultural research, expenditure on extension services and population growth rate using Augmented Dickey-Fuller test in level, first difference and second difference.

Table 4.4: Unit root test results for the series in levels

Variable	ADF Statistic	p-value	Order of Integration
Log (agricultural productivity)	-2.190	0.482	Non stationary
Log (agricultural capital)	-1.540	0.799	Non stationary
Log (research and development investments in agricultural research)	-4.899	0.002	I(0)
Log (expenditure on extension services)	-2.329	0.410	Non stationary
Log (population growth rate)	-5.286	0.001	I(0)

Note: *H_0: the series are non-stationary. H_0 is rejected if the absolute value of ADF test statistic exceeds the critical values at 5%. ADF = Augmented Dickey Fuller. 5% critical value = 3.472*

The results in Table 4.4 indicate that all the variables were not stationary in level apart from research and development investments in agricultural research and population growth rate at 5 percent level since their ADF statistic in absolute terms was less than the critical value (3.472). Thus, variables; agricultural productivity, agricultural capital and expenditure on extension services the series were further differenced to achieve stationarity.

Table 4.5: Unit root test results for the series in first difference

Variable	ADF Statistic	p-value	Order of Integration
Log (agricultural productivity)	-3.294	0.081	Non stationary
Log (agricultural capital)	-3.522	0.049	I(1)
Log (expenditure on extension services)	-3.199	0.098	Non stationary

The results in Table 4.5 show that even after first differencing variables, agricultural productivity and expenditure on extension services were non stationary even after first differencing at 5% level apart from agricultural capital since their ADF statistic in absolute terms was less than the critical value (3.472). This necessitated second differencing in order to achieve stationarity.

Table 4.6: Unit root test results for the series in second difference

Variable	ADF Statistic	p-value	Order of Integration
Log (agricultural productivity)	-8.198	0.000	I(2)
Log (expenditure on extension services)	-8.288	0.000	I(2)

Upon second differencing, the results in Table 4.6 showed that agricultural productivity and expenditure on extension services became stationary. This was due to the fact that their ADF statistic in absolute terms was less than the critical value (3.472) at 5% level. Thus, the null hypothesis of non-stationarity was rejected and hence these variables become stationary and are integrated of order two.

In conclusion, variables; research and development investments in agricultural research and population growth were stationary in level while agricultural capital was stationary at first differencing and agricultural productivity and expenditure on extension services were stationary at second differencing. Hence, they were integrated of their respective orders hence existence of a long-run relationship among the variables.

4.2.4 Testing for co-integration

4.2.4.1 Co-integration analysis using Johansen's Approach

The procedure was applied to test whether there was some cointegration and the number of cointegrating equations between agricultural productivity, agricultural capital, research and development investments in agricultural research, expenditure on extension services and population growth rate and the results are presented in Table 4.7.

Table 4.7: Johansen Unrestricted Cointegration Rank Test

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.624	41.033	33.877	**0.006**
At most 1	0.435	23.963	27.584	0.136
At most 2	0.373	19.596	21.132	0.081
At most 3	0.244	11.752	14.265	0.120
At most 4	0.004	0.185	3.841	0.667
Trace test indicates 1 cointegrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values				

The unrestricted maximum eigenvalue cointegration rank test results show that the Maximum eigen statistic (41.033) exceed the 5 percent critical value (33.877) implying that there is only one cointegrating vector among all variables in the model. According to Gujarati (2004), if cointegration is accepted, then there is a long run relationship among the non-stationary series.

4.3 Results of long run model

The long-run model was estimated using a log-log model. The model was first subjected to the coefficient and diagnostic tests. Table 4.8 presents the multicollinearity test using the Variance Inflation Factor (VIF).

Table 4.8: Multicollinearity test using Variance Inflation Factor

Variable	Centered VIF
LOG(AI)	1.970
LOG(IRD)	1.499
LOG(EXT)	1.033
LOG(POPGR)	1.476

Results in Table 4.8 indicate no significant problems of multicollinearity between agricultural productivity, and agricultural capital, research and development investments in agricultural research, expenditure on extension services, and population growth rate. This was due to the fact the centered VIF was less than 10 which according to Hair et al., (1995) is the maximum level of VIF.

Furthermore, Table 4.9 presents results of the long run model. According to results in Table 4.9, the test for normality of the error term was conducted and the Jarque-Bera from the histogram of the residuals suggested that the error term was normally distributed. The p-value of the Jarque-Bera statistic (p=0.086) exceeded 0.05 level of significance hence, the null hypothesis that the residuals were normally distributed could not be rejected. Thus, the model is fit and reliable in explaining the determinants of agricultural productivity. Also, the test for serial correlation among residuals in the model using Breusch-Godfrey Serial Correlation LM test was carried out. The results indicate F-statistics of 3.837 with its corresponding probability value of 0.179 confirming no serial correlation among the residuals. Besides, the Breusch-Pagan-Godfrey Heteroskedasticity test provided no evidence of believing that the residual term of the model residuals wasn't homoscedastic since the p-value is 0.074.

Table 4.9: Results of the regression model

Dependent Variable: LOG(AGVA) Method: Least Squares Sample: 2007Q1 2017Q4			
Variable	**Coefficient**	**Std. Error**	**Prob.**
C	1.5631	0.4886	0.0027**
LOG(AI)	0.0070	0.0071	0.3265
LOG(IRD)	0.0305	0.0100	0.0168*
LOG(EXT)	0.2971	0.0446	0.0042**
LOG(POPGR)	2.9279	0.2772	0.0000**
R-squared 0.807 F-statistic 40.676	Adjusted R-squared 0.787 Prob(F-statistic) 0.000	S.E. of regression 0.029	
Residual and stability diagnostic tests Normality Test: Jarque-Bera 4.908 (0.086) Serial correlation: Breusch-Godfrey Serial Correlation LM Test: F-stat 3.837 (0.179) Heteroskedasticity Test: Breusch-Pagan-Godfrey, F-statistic 2.320 (0.074)			

*Note: The asterisk ** and * indicate significance at the 1 percent and 5 percent levels respectively.*

4.3.3 Discussion of the Long-run results

The empirical results from the long-run model in Table 4.9 are interpreted in the following sub sections.

Research and development investments in agricultural research

The coefficient of research and development investments in agricultural research was positive and significant at 5 percent level. Thus, assuming all other factors constant, a 1-percent increase in research and development investments in agricultural research would lead to a 0.031-percent increase in agricultural productivity in Uganda. The findings of this study are in agreement with the findings of Alston et al., (2011), Fuglie and Toole (2014), Wang et al., (2013), Rahman and Salim (2013), Voutsinas and Tsamadies (2014) and Farid and Ruhul (2015). According to Alston et al., (2011), Fuglie and Toole (2014) and Wang et al., (2013) R&D investments in agricultural research provided new knowledge and technologies that fuelled improvements in agricultural productivity in US agriculture. Wang et al., (2013) added that R&D affects agricultural productivity only over the long-term. Similar evidence is also found for developing countries. For example, a study by Rahman and Salim (2013) in Bangladesh shows that R&D investment is one of the significant aspects that favourably affect agricultural productivity. Furthermore, Voutsinas and Tsamadies (2014) have found that R&D expenditure in Greek agricultural improves the rate of technological innovation, which affects long-run agricultural productivity growth. In addition, Farid and Ruhul (2015) investigated the effects of R&D on Agricultural Productivity of Australian Broadacre Agriculture: A Semiparametric Smooth Coefficient Approach was used. The empirical results show that once both the direct and indirect effects are taken into consideration, R&D investments significantly increase agricultural productivity.

Expenditure on extension services

The coefficient of expenditure on extension services was positive and significant at 5 percent level. Thus, assuming all other factors constant, a 1-percent increase in expenditure on extension services would lead to a 0.297-percent increase in agricultural productivity in Uganda. Agricultural extension service is one of the most common mechanisms of transferring knowledge and skills to farmers as support to apply them to the real world (McDowell, 1929). The primary objectives of the agricultural extension service include providing information and educating them how to apply core principles of improved technologies to farm practices (Anderson and Feder, 2004; Rivera, Alex, Hanson and Birner, 2006). Moreover, extension activities help farmers form group and work with many institutions with an aim of increasing agricultural productivity, and assist them to market their agricultural products (Jamison and Moock, 1984). Therefore, effective agricultural extension can contribute to improve agricultural productivity, increased output, and household income for the economy by bridging the gap between educational discoveries in extension providers and status in individual farmers (Birkhaeuser, Evenson and Feder, 1991). Thus, the study results are in agreement with all these studies in addition to the Huffman, (1976) and Owens, Hoddinott and Kinsey, (2003) who found that extension has contributed to increased agricultural productivity and farm income.

Population growth rate

The coefficient of population growth rate was positive and significant at 5 percent level. Thus, assuming all other factors constant, a 1-percent increase in population growth rate would lead to a 2.928-percent increase in agricultural in Uganda. The findings of this study are in agreement with the findings of the Muraya and Ruigu (2017) and Enu and Attah-Obeng (2013). According to Muraya and Ruigu (2017), labour force, rainfall, and government expenditure had a positive impact on agricultural productivity in Kenya in the long run while Enu & Attah-Obeng (2013) on establishing the macro determinants of agricultural productivity in Ghana for the period 1980 to 2011 using a Cobb-Douglas production function and ordinary least squares estimation technique to analyze the data found that Labour force, inflation, real exchange rate, real GDP per capital, were significant in determining agricultural productivity.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary of the major findings and recommendations. The study was conducted for the purpose of establishing the determinants of agricultural productivity in Uganda. Descriptive statistical and econometric methodologies were utilized to analyze the data. Hence, this chapter reviewed and summarized the research paper and identified the recommendations for policy.

5.1 Summary of findings

The results of unit root tests using Augmented Dickey Fuller showed that research and development investments in agricultural research and population growth were stationary in level while agricultural capital was stationary at first differencing and agricultural productivity and expenditure on extension services were stationary at second differencing. Hence, they were integrated of their respective orders hence existence of a long-run relationship. The long run relationship was further confirmed by the unrestricted maximum eigenvalue cointegration rank test which found the presence of only one cointegrating vector among all variables.

Emanating from the regression results; coefficient of research and development investments in agricultural research (=0.031, p=0.017) was positive and significant at 5 percent level. Thus, assuming all other factors constant, a 1-percent increase in research and development investments in agricultural research would lead to a 0.031-percent increase in agricultural productivity in Uganda. coefficient of expenditure on extension services (=0.297, p=0.004) was positive and significant at 5 percent level. Thus, assuming all other factors constant, a 1-percent increase in expenditure on extension services would lead to a 0.297-percent increase in agricultural productivity in Uganda. The coefficient of population growth rate (=2.928, p=0.000) was positive and significant at 5 percent level. Thus, assuming all other factors constant, a 1-percent increase in population growth rate would lead to a 2.928-percent increase in agricultural in Uganda.

5.2 Conclusions

The determinants of agricultural productivity are; research and development investments in agricultural research, expenditure on extension services and population growth.

With regard to the findings, the following hypotheses were not supported; (1) There is no significant relationship between agricultural extension/technology transfer and agricultural productivity and (3) There is no significant relationship between research and development investments in agricultural research and agricultural productivity. On the other hand, the following hypothesis was supported; (2) There is no significant relationship between agriculture capital and agricultural productivity.

5.3 Policy Recommendations

Technological improvement is one of the key sources of agriculture productivity growth since it can change the production process by applying innovation, newly achieved scientific and practical knowledge and through management skills. The reason is that new technological knowledge is considered as the outcome of research (Antle and Capalbo, 1988). Therefore, there is need for increased investment in Uganda's agriculture research and development for its agricultural productivity to increase.

5.4 Recommendations for further research

Agriculture provides a livelihood to a significant portion of population in developing countries more especially in the rural and agrarian areas where poverty is more prominent. However, intensive agricultural production systems may also have some environmental and equity problems hence, further research can review agricultural productivity along with environmental degradation.

REFERENCES

Alston, J. M., J. M. Beddow and P.G. Pardey, (2009). Agricultural Research, Productivity, and Food Prices in the Long Run. A recent summary of the evidence. *Science* 325 (4): 1209–1210.

Alston, J.M., Babcock, B.A. and Pardey, P.G. (2011). The Shifting Patterns of Agricultural Production and Productivity Worldwide. CARD-MATRIC Electronic Book. Ames, IA: *Center for Agricultural and Rural Development.*

Ahmad, K. (2012). Determinants of Agriculture Productivity Growth in Pakistan. *International Research Journal of Finance and Economics*, 1450-2887(95), 164-172.

Antle, J. and S. Capalbo, (1988). *An introduction to recent developments in production theory and productivity measurement*. Johns Hopkins University press, Washington, DC.

Amone. W (2017). Agricultural Productivity and Economic Development in Uganda: An Inclusive Growth Analysis. *Mbarara University of Science and Technology*, Unpublished Ph. D thesis.

Anyanwu, S. (2013). Determinants of Aggregate Agricultural productivity among high external inputs technology farms in a harsh macroeconomic environment of IMO state, Nigeria. *African Journal of Food, Agriculture, Nutrition and Development*, 13(5), 8238-8248.

Auraujo, B., C. G. Chambas, and J. P. Foirry, (1997). *Consequences de l'ajustement des finances publiques sur l'agriculture marocaine et tunisienne*. Unpublished FAO study, March.

Ayinde, O., Muchie, M., & Olatunji, G. (2011). Effect of Climate Change on Agricultural Productivity in Nigeria. *Journal of Human Ecology*, 35(3), 189-194.

Benin, S., Mogues, T., Cudjoe, G., & Randriamamonjy, J. (2009). Public Expenditure and Agricultural Productivity Growth in Ghana. Beijing: *International Food Policy Research Institute*.

Block, S., (1994). A new view of Agricultural Productivity in Sub-Saharan Africa. *American Journal of Agricultural Economics*, 76 August: 619-624.

Brownson, S., Vincent, I.-M., Emmanuel, G., & Etim, D. (2012). Agricultural Productivity and Macro-Economic Variable Fluctuation. *International Journal of Economics and Finance*; 4(8), 114-125.

Cesar. A. L, Lina. S and Carmine. P. D (2017). Agricultural Input Subsidies and Productivity: The Case of Paraguayan Farmers. *IDB Working Paper Series* Nº IDB-WP-802.

Chavas, J. P., (2001). An International Analysis of Agricultural Productivity. *FAO Economic and Social Development Paper*: 148.

Chauvin, N.D., Mulangu, F., & Porto, G. (2012). Food production and consumption trends in Sub-Saharan Africa: prospects for the transformation of the agricultural sector. *UNDP Working Paper*, No. 2012-011. Retrieved October 8, 2020 from http://www.undp.org/content/dam/rba/docs/Working%20Papers/Food%20Production%20and%20Consumption.pdf

Dickey, D. and Fuller, W. (1979). Distribution of the Estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association, 74* (366): 427-431.

Diiro. G. M (2017). Strategies to raise agricultural productivity, address gender inequalities, and reduce rural poverty in Uganda. *Africa in Focus.*

Ekborn, A. (1998). Some Determinants of Agricultural Productivity - an Application of Kenyan Highlands. Washington D.C. 20433 U.S.A: *World Bank, African Region, Environmental group* (J3-141), 1818H St.

Engel, R. F. and Granger, C. W. J. (1987). Co-integration and Error Correction: Representation, Estimation and Testing. *Econometrica*, *55* (2): 215-276.

Enu, P., & Attah-Obeng, P. (2013). Which Macro Factors Influence Agricultural Production in Ghana. *Academic Research International, 4*(5), 333-346.

Ewubare. D. B and Eyitope. J. A (2015). The Effects of Public Expenditure on Agricultural Production Output in Nigeria. *Journal of Research in Humanities and Social Science.*

Evenson, R. E. and J. J. W. McKinsey, (1991). Research, Extension, Infrastructure, and productivity change in Indian agriculture. *Research and productivity in Asian agriculture*, p. 158-184. Ithaca, USA, Cornell University Press.

Evenson, R.E. and Y. Kislev, (1975). Agricultural Research and Productivity. *New Haven: Yale University Press*.

Fan, S., Johnson, M., Saurkar, A. & Makombe, T. (2008). Investing in African Agriculture to Halve Poverty by 2015. *IFPRI Discussion Paper* 00751.

Fan, S., (1996). Research Investment, Input Quality, and the Economic Returns to Chinese Agricultural Research. *Paper Presented to the Post-Conference Workshop on Agricultural Productivity and R&D Policy in China, Conference Proceedings for Global Agricultural Science Policy for the Twenty-First Century*. 16-28 August 1996, Melbourne, Australia.

FAO (2009a). *How to Feed the World in 2050*? FAO. Accessed on: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

FAO (2009b). Feeding the World in 2050. Accessed on: http://www.fao.org/tempref/docrep/fao/meeting/018/k6021e.pdf

FAO (2011). *The state of food and agriculture*. FAO, Rome, Italy.

FAO (2013). *Promoting investment in agriculture for increased production and productivity*. Rome, Italy.

Farid. K and Ruhul. S (2015). The Effects of R&D on Agricultural Productivity of Australian Broadacre Agriculture: A Semiparametric Smooth Coefficient Approach; *Selected Paper prepared for presentation at the 2015 Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting*, San Francisco, CA, July 26-28.

Fuglie, K. O., & Rada, N. E. (2013). Resources, policies, and agricultural productivity in Sub-Saharan Africa. *Economic Research Report Number 14*. Washington D.C: United States Department of Agriculture

Fuglie K. O, & Toole, A. A (2014) The Evolving Institutional Structure of Public and Private Agricultural Research. *American Journal of Agricultural Economics*. doi: 10.1093/ajae/aat107

GHI (2015). Global Agricultural Productivity Report, *Global Harvest Initiative* (GHI's), Washington, D.C., October 2015.

Gilberto. M. L (2012). The Impact of Infrastructure on Agricultural Productivity. *Philippine Institute for Development Studies, Discussion Paper Series* NO. 2012-12.

Green, W. H. (1993). *Econometric Analysis.* Second Edition, Macmillan, New York.

Gujarati, D., (2004). *Basic Econometrics-Economic series McGraw-Hill international editions* (fourth). McGraw-Hill. Retrieved from http://doi.org/10.2307/2344828

Hair, J. F. Jr., Anderson, R. E., Tatham, R. L. & Black, W. C. (1995). *Multivariate Data Analysis* (3rd ed). New York: Macmillan.

Hasan, R., & Quibria, M. G. (2004). Industry matters for poverty: A Critique of agricultural fundamentalism. *Kyklos,* 57(2):253–64.

Jamison D. and L. Lau, (1982). Farmer Education and Farm Efficiency. Washington, DC, *World Bank.*

Johansen, S. and Juselius, K. (1990). Maximum Likelihood Estimation and Inferences on Cointegration with Applications to the Demand for Money. *Oxford Bulletin of Economics and Statistics*, Vol. 52, pp 169-210.

Lachaal, L., (1994). Subsidies, Endogenous Technical Efficiency and the Measurement of Production Growth. *Journal of Agriculture and Applied Economics*, 26(1): 299-310.

Li, X., & Prescott, D. (2009). Measuring Productivity in the Service Sector Canadian Tourism.

Kumar, A., & Sharma, P. (2013). Impact of Climate Variation on Agricultural. *Economics E-Journals*, 2013-43.

MAAIF. (2010). *Agriculture for Food and Income Security: Agriculture Sector Development Strategy and Investment Plan*, 2010/11–2014/15, Kampala.

Maddala, G. (1992). *Introduction to Econometrics*. New York: Macmillan Publishing Company.

Mozumdar, L. (2012). Agricultural Productivity and Food Security in the Developing World. *Bangladesh Journal Agricultural Economics* XXXV, 1&2(2012) pp 53-69.

MAFAR (2013). Review of Food and Agricultural Policies in Uganda 2005-2011. *MAFAP Country Report Series*, FAO, Rome, Italy.

Nabbumba, R., & Bahiigwa, G. (2003). Agricultural productivity constraints in Uganda: implications for investments. *Research Series no. 31. Kampala: EPRC*.

Odhiambo, W., Nyangito, H. O., & Nzuma, J. (2004). Sources and Determinants of Agricultural growth and productivity in Kenya. Nairobi, Kenya: *Kenya Institute for Public Policy Research and Analysis(KIPPRA*), Discussion paper No. 34.

OECD/FAO (2016). *Agricultural Outlook* 2016-2025. Accessed on: http://www.fao.org/3/a-i5778e.pdf

Rahman S, Salim R (2013) Six Decades of Total Factor Productivity Change and Sources of Growth in Bangladesh Agriculture (1948–2008). *Journal of Agricultural Economics* 64(2): 275-294

Shittu, A.M., & Odine, A.I. (2014). Agricultural Productivity Growth in Sub-Sahara Africa, 1990-2010: The Role of Investment, Governance and Trade. *Paper presented at the 17th Annual conference on Global Economic Analysis*, Dakar, Senegal.

Voutsinas I, Tsamadias C (2014) Does Research and Development Capital Affect Total Factor Productivity? Evidence from Greece. *Economics of Innovation and New Technology* 23(7): 631-651

Wang SL, Heisey PW, Huffman WE, Fuglie KO (2013) Public R&D, Private R&D, and U.S. Agricultural Productivity Growth: Dynamic and Long-Run Relationships. *American Journal of Agricultural Economics* 95(5): 1287-1293

World Bank. (2007). World development report 2008: Agriculture for development. Washington, DC: *World Bank*.

World Bank. (2008). Agriculture for development. World Development Report 2008: Washington DC: *World Bank*.

Zepeda, L. (2001). Agricultural Investment, Production Capacity and Productivity. In L. Zepeda, eds. "Agricultural Investment and productivity in Developing Countries". *FAO Economic and Social Development Paper*: 148.