

**AN ECONOMIC ANALYSIS OF THE FACTORS
INFLUENCING MAIZE PRODUCTIVITY AND
EFFICIENCY IN RWANDA: A CASE STUDY OF
GATSIBO DISTRICT**

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**An economic analysis of the factors influencing maize productivity and
efficiency in Rwanda: a case study of Gatsibo District**

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DECLARATION

This thesis is my original work and has not been presented for any degree in any other university.

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DEDICATION

I dedicate all of my works and life to Jesus Christ, the only Son of almighty God.

This Thesis is kindly dedicated to my beloved Parents, my beloved Girlfriend, my Daughter Esperance and Brothers Innocent, Samuel, Elie, Jean de Dieu and to all my friends.

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LIST OF ACRONYMS AND ABRVIATIONS

AE:	Allocative Efficiency
APP:	Average Physical Product
CAADP:	Comprehensive Africa Agricultural Development Programme
CIMMYT:	International Maize and Wheat Improvement Center
DDP:	District Development Plan
DRC:	Democratic Republic of Congo
EDPRS:	Economic Development and Poverty Reduction Strategy
EE:	Economic Efficiency
EICV:	Integrated Household Living Conditions Survey
EP:	Elasticity of Production
FAO:	Food and Agricultural Organization
FRW:	Rwandan Francs
GDP:	Gross Domestic Product
GNI:	Gross National Income
ISAR:	Rwanda Institute for Agronomic Sciences
MINAGRI:	Ministry of Agriculture and Animal Resources
MINECOFIN:	Ministry of Finance and Economic Planning
MPP:	Margin Physical Product

NGO:	Non-Governmental Organization
NISR:	National Institute of Statistics of Rwanda
RDI:	Rwanda Development Indicator
RDO:	Rwanda Development Organization
RTS:	Returns to scale
SPSS:	Statistical Package of Social Sciences
TBE:	Technical Efficiency
TPP:	Total Physical Product

ABSTRACT

Agriculture plays an important role in raising the economy of Rwanda. Maize is one of the dominant crops that has a good productivity in the study area. An efficient use of the existing resources by farm households improves their productivity and thereby increases their output. Most researches on agriculture focused on how to achieve certain level of yield. However, few researches consider rational resource allocation to improve productivity efficiency. The main objective of the study was to conduct an economics analysis of the factors influencing maize productivity and efficiency among farmers in Rwanda. The first specific objective of this study was to determine the production factors influencing maize productivity in study area, the second objective was to find out socio-economic and institutional factors influencing technical, allocative, and economic efficiency among maize farms in study area. This study was based on the cross-sectional data collected in July 2015. A multi-stage sampling procedure was applied to the population of maize farmers from the area under study and 168 respondents were proportionally selected from seven zones of farming. A Stochastic production frontier model was used to estimate technical, allocative and economic efficiency levels, whereas Tobit model was used to identify factors affecting efficiency levels. The result showed that the maximum yield of maize is 4800 kg/ha. The average values for seeds and chemical fertilizer inputs ranges between 10-21.4 and 20-67 kg per hectare, respectively. The maximum organic manure used was of 10000kg/ha. The average value for pesticide used was 1.54 litter /ha. The average figure for labor is 178 person-days per hectare. The study result indicated that the mean technical, allocative, and economic efficiency score for the sampled farms were 51.78%, 63.17%, and 54.17 % respectively. It was found that improved seeds, land size, organic manure, labor and chemical fertilizer positively and significantly influenced maize productivity. Factors such as access to credit; extension services, work experience in maize production; and family income were found to be statistically significant at 1% level on the influence of the technical efficiency in the study area. However, household head age and distance to market showed a negative and significant effect on technical, allocative and economic

efficiency of the maize farms. Thus, government agencies especially Rwanda Agriculture Board and local government and researchers should take into consideration the above indicated production, socio-economic and institutional factors to improve productivity of maize in the study area.

CHAPTER ONE:

INTRODUCTION

1.1 Background

Agriculture is still an important pillar of our planet's economy. The sector plays important roles in the development process of any nation by supplying food items, industrial inputs, generating foreign exchange, creating employment opportunities, contributing to gross domestic product (GDP) and expanding markets for industrial outputs. According to World Bank (2007), agriculture is the major source of income and employment for about 70 percent of the world's rural poor societies and 32 percent in the growth of GDP in these countries. Globally, (75%) of the world's poor in rural areas and most of them dependent on farming, agriculture must be part of world economic growth, poverty reduction, and environmental sustainability (UNDP, 2012).

Maize is the global leading cereal in terms of production, with 1,016 million metric tonnes (MMT) produced on 184 million hectares (M ha) globally (FAOSTAT, 2013). Maize is produced globally across temperate and tropical zones and spanning all continents. The maize agri-food systems CRP focuses on (sub-)tropical maize in the low- and middle-income countries that provide 64% of total maize production and where maize plays a key role in the food security and livelihoods of millions of poor farmers. Maize is one of the three leading global cereals that feed the world Shiferaw *et al.*, (2011). Maize, together with rice and wheat, dominate human diets (Ignaciuk, 2014) and provide at least 30% of the food calories of more than 4.5 billion people in 94 developing countries.

Maize's central role as a staple food in Africa and Central America. It is comparable to that of rice or wheat in Asia, with consumption rates being the highest in eastern and southern Africa (ESA). Maize accounts for almost half of the calories and protein consumed in ESA, and one-fifth of the calories and protein consumed in West Africa. In

Mesoamerica, annual maize consumption exceeds 80 kg per capita in El Salvador, Guatemala, Honduras and Mexico Shiferaw *et al.*, (2011). Although direct maize consumption is lower in South and Southeast Asia, there are several areas in the highlands and tribal regions (e.g., Nepal, Bhutan, India, southern China, southwestern Bangladesh, Indonesia and the Philippines) where maize is a main staple (Prasanna, 2014). However, hunger remains widespread. Approximately 925 million people experience hunger. They lack access to sufficient of the major macronutrients (carbohydrates, fats and protein). Perhaps another billion suffer from “hidden hunger,” where important micronutrients (such as vitamins and minerals) are missing from their diet (UN Standing Committee on Nutrition, 2004; World Bank, 2006a).

With its multiple uses, maize is the world’s most multi-purpose crop. Aside from its staple food use, it makes a significant contribution to animal feed (especially poultry) as well as bio-fuel and industrial uses. Population growth, changing diets and a rapidly growing poultry sector are contributing to a sharp increase in maize demand. During 1991-2011, total utilization of maize almost doubled in Asia. Global population will increase from nearly seven billion today to eight billion by 2030, and probably to over nine billion by 2050. Rising income levels and a growing urbanized population (especially in populous developing countries) that eats an increasingly diversified diet, will dramatically increase and change the demand for food and feed and influence and compete with alternative uses such as industrial and biofuel. Global cereal production is expected to increase by almost 370 MT through the next decade, reflecting a growth of 15% by 2023 (OECD-FAO, 2014). By 2050, the global demand for maize could increase by 50% (Ignaciuk, 2014). Timsina *et al.* (2011) suggested that, by 2020, maize demand alone in Asia might increase by as much as 87%. Developing regions will account for more than 75% of additional agricultural output over the next decade (OECD-FAO, 2014).

The planted land of maize and grain production have increased significantly across regions in SSA since 1961 (FAOSTAT, 2013). Of the 22 countries in the world where

maize forms the highest percentage of calorie intake in the national diet, 16 are in Africa (Nuss & Tanumihardjo, 2011).

Agriculture is critical to achieving global poverty reduction targets and it is still the single most important productive sector in lowest income countries. In most poor countries, especially in sub-Saharan Africa, large majorities of the population live in rural areas and earn their livelihoods primarily from agriculture (Gollin, 2009).

The majority of the poor and food insecure in Africa live in rural areas, and most of them depend on agriculture for their livelihoods. To support broad-based poverty reduction and food security in Africa, smallholder agriculture must be a central investment focus (Garvelink *et al.*, 2012).

In Africa Cereal, yields are lower than half the world average. The average fertilizer (N + P₂O₅) consumption is 16.24 kg/ha (FAOSTAT, 2010) which is 1/6th compared to the world consumption of 98.20 kg/ha. Increasing productivity of the small holder farmers, bridging the yield gaps by providing appropriate inputs along with improved technologies such as stress resistant and high yielding varieties and empowering farmers to better manage climate risk will be will be huge step towards agricultural transformation in Africa.

Maize is a major staple food crop grown in diverse agro-ecological zones and farming systems, and consumed by people with varying food preferences and socio-economic backgrounds in sub-Saharan Africa (SSA). The central role of maize as a staple food in SSA is comparable to that of rice or wheat in Asia, with consumption rates being the highest in eastern and southern Africa (ESA). It is the most widely grown staple food crop in sub-Saharan Africa (SSA) occupying more than 33 million ha each year (FAOSTAT, 2013).

The crop covers nearly 17% of the estimated 200 million ha cultivated land in SSA, and is produced in diverse production environments and consumed by people with varying

food preferences and socio-economic backgrounds. More than 300 million people in SSA depend on maize as source of food and livelihood (<http://dtma.cimmyt.org/index.php/background>). The top 20 countries, namely South Africa, Nigeria, Ethiopia, Tanzania, Malawi, Kenya, Zambia, Uganda, Ghana, Mozambique, Cameroon, Mali, Burkina Faso, Benin, DRC, Angola, Zimbabwe, Togo, and Cote d'Ivoire, account for 96% of the total maize production in SSA (FAOSTAT, 2013).

Maize accounts for almost half of the calories and protein consumed in ESA, and one-fifth of the calories and protein consumed in West Africa. Regional average yields are as high as 1.7 t/ha in West Africa and 1.5 t/ha in East Africa, and 1.1 t/ha in Southern Africa Smale *et al.*, (2011). Even though some countries (e.g., Ethiopia with >3 t/ha) have made significant productivity gains, the average yield of maize in SSA (estimated at <1.8 t/ha) is still far below the global average yield of maize (~5 t/ha) and considerably below the 4.4-5.4 t/ha on-farm trial results of improved varieties under optimal inputs and improved management conditions undertaken by CIMMYT/IITA within SSA.

Regionally, maize is a very important food crop. It is an ancient crop consumed as healthy and staple food by more than half of the world population. By use of recommended inputs such as improved varieties, fertilizers, pesticides and update technologies within East Africa, Tanzania is number one producer followed by Kenya and Uganda in that order. In Kenya, Nakuru district alone produces 200,000 tonnes per annum, which is about 4 times more than the whole of Rwanda (FAO, 2007).

Agriculture is the main economic sector in Rwanda and contributes significantly to national development. A sector receives high priority and attention from the Rwandan Government. Agriculture has been the major driver of the Rwandan economy over the years, providing employment for about 70 percent of the population and accounting for more than one third of total gross domestic product (GDP) and product labor force

(FAO,2005). The sector made a remarkable contribution to the gross domestic product. Hence, the ability of agriculture to generate overall GDP growth and its comparative advantage in reducing poverty will vary from country to country (FAO, 2012).

In its Policy on Economic Management for Renewed Growth, the Rwandan Government stated that self-sufficiency in the production of agricultural products such as maize, beans, Rice, cassava, Irish potatoes, and wheat and Horticultural crops is a key strategy for sound economic management and renewed growth for the country. For the agricultural sector to play this central role in a sustainable way, rapid growth in output and productivity is critical. It is widely recognized that the sustained flow and use of improved agricultural technologies is key to increased growth and agricultural productivity.

The Rwandan economy is based on the largely rain-fed agricultural production of small, semi-subsistence, and increasingly fragmented farms. It has few natural resources to exploit and a small, noncompetitive industrial sector (MINECOFIN, 2013). Currently maize is a major food crop and dominates all national food security considerations in Rwanda. Maize (*Zea mays*) is one of the major important staple crops in Rwanda where it ranked the fifth among food crops and second among cereals after sorghum. Maize occupied about 32% of the land allocated to cereal production in Rwanda (MINAGRI; 2009). Maize is currently grown in all five (5) provinces of Rwanda and is essentially intercropped with beans. Regarding to cultivated area and production of maize ranks third (14%) in Rwanda followed by bean (21.2%) and banana (19.6%) (MINAGRI; 2009).

In Gatsibo Agriculture in terms of crop production and livestock is the principle economic activity. According to EICV3, 84.9 % of Gatsibo population both men and women basically depend on agriculture whom, at least 80% use traditional agriculture practices. The major food crops produced are beans, rice, Irish potatoes sweet potatoes, bananas, sorghum, cassava, passion fruits, peas, maize and soya. According to EICV3,

Maize crop production is 49.2%, sorghum is 28.3% and Rice 2.2% while the key cash crops are coffee and pepper. Usage of inputs like fertilizers is relatively low at (49.5%EICV3) of farming households (NISR, 2012).

Almost all agro-climatic zones of the country have great suitability in the production of maize. This study was carried out to determine the factors that influence maize production among farmers in Gatsibo district. The factors are those, which facilitate to increase maize production such as improved maize varieties, fertilizers and factors of production namely land, labor, capital and entrepreneurship. Maize is mainly grown by 62% of farm households for various purposes such as to increase the population's access to food, improve nutrition, and reduce poverty in rural areas, to ensure food security for all of the population, increase households' income, and reduce in poverty. Generally maize plays an important role in the socio-economic life of rural households found by (Terpend *et al.*,2008).

Some of the reasons for the low value inputs use relating to low productivity of maize are connected with fluctuations of water table, and attendant dangers of flooding, inadequate water supply at the end of the dry season, shortage of agrochemicals, usage of unimproved seeds, crude mode of production, high cost of labor among others are the main causes of low productivity for many crops including maize .It can be seen that smallholder farmers may be affected, as they are producers and consumers of goods. Thus, the government of Rwanda need to put proper policies that support these farmers, to ensure their overall welfare is not compromised.

Therefore, this study is to complement the various efforts of research in improving maize production in Rwanda. This information assist maize research and extension to develop suitable technologies and target them appropriately to farmers in different environments and from different socioeconomic domains. The analysis enables policy makers to identify policy and institutional factors that can contribute to increased

adoption of high yielding maize technologies as well as increasing maize productivity & per unit area.

1.2 Problem statement

Many low developing countries including Rwanda, use of high value farm inputs is associated with high agricultural production (MINAGRI, 2011). Unfortunately in Rwanda high value inputs are used on very small proportions. Moreover, there was no study regarding the efficiency of maize productivity in the study area. Agricultural output can be increased either through introduction of modern technologies or by improving the efficiency of inputs such as labour and management at the existing technology.

The existing production system of maize suffers from traditional farming practices, unimproved seed, low fertilizer use, etc. This situation has caused productivity of the crop to be far below the estimated FAO potential, which is about 2.3 tons /ha Wijnands *et al.*, (2007) as cited in Sorsa, 2009. A food consumption survey showed that maize products was the most often consumed staple in Rwanda, with 40% of the population eating it at least once a week (NISR, 2012). In many countries, including Rwanda, non-farm chemical inputs play a large role in agricultural production, especially because of the need to increase production.

The declining trends on quantities of maize produced has been evident at the global and regional level with a majority of the world producers of maize recording significant declines in the quantities of maize exported while million hectare of maize, estimated on the basis of crop area surfaces) is found in Africa and potential yields are highly variable between 5 and 10 t/ha, and typical farm yields are in the range 1-3 t/ha. Low levels of agricultural production have been the major problem facing the Rwandan economy for many years (Pingali, 2001).

Small-scale farmers are amongst the vulnerable groups in rural areas, most of them are women, children and the aged. It is alleged that most small-scale farmers in rural areas

are inefficient due to over or under utilization of some of the factors of production. This in turn leads to food insecurity and poverty (Baloyi *et al.*, 2011).

Given the existing of new technology, improvements in the technical efficiency will enable farmers to produce the maximum possible output from a given level of inputs. Hence, improvements in the level of technical efficiency will increase productivity. Yet empirical works on the farm level technical efficiency is limited and knowledge of farmer's production situations remain inadequate particularly in Sub-Saharan Africa. Limited studies have conducted on economic aspects of maize productivity in Rwanda. The major goal of any production system is the attainment of an optimally high level of output with a given amount of effort or input (Rahman, 2013). The current study was meant to focus on factors influencing maize productivity and to show the efficiency level and identify socio-economic factors affecting the technical, allocative and economic efficiency of farmers in Gatsibo, Rwanda.

1.3 Objectives

1.3.1 General objective

The broad objective of this study was to conduct an economics analysis of the factors influencing maize productivity and efficiency among farmers in Gatsibo district, Rwanda.

1.3.2 The specific objectives

The specific objectives of this study include the following:

1. To determine the production factors influencing maize productivity in study area.
2. To find out socio-economic and institutional factors influencing technical, allocative and economic efficiency among maize farms in study area.

1.4 Hypothesis

1. Productivity of maize is significantly influenced by land size, improved seeds, organic manure, labor, and chemical fertilizer;
2. Technical, allocative and economic efficiency are positively influenced socio-economic and institutional factors

1.5 Justification of the study

Maize is one of the five priority crops that have been chosen by the Government of Rwanda in its effort to increase household incomes and the nutritional status of the Rwandan people through increased production and marketing (MINAGRI, 2007). This depends on the fertile soil of Gatsibo district and good understanding of the region and the farmers on crop intensification program. By conducting this research on the analysis of factors influencing maize productivity and efficiency among farmers in Gatsibo district.

Maize is also an important cereal crop cultivated in virtually all parts of Rwanda. It was generally considered as low status food of the rural people due to its low cost comparative to beans for example. The crop also provides farm households and traders with incomes and is therefore important from both the food security and income-generation points of view (MINAGRI, 2011). This gave some advice to the agricultural Extensionists, Agricultural policy makers and many researchers to improve their program's effectiveness (MINAGRI, 2011).

1.6 Scope of the study

The studied area is suitable agro-climatic zone among farmers of maize crop. The farmers in the study area produce different types of crops. Farmers in the study area mainly produce cereal crops. Maize is the most important cereal crop grown in terms of area coverage and total quantity produced. This study focused only on maize crop and other crops were not included where farmer households involved in maize cultivation as

commercial purpose were more preferable. The scope of this study was to analyze the factors influencing maize production productivity and efficiency in Rwanda a case study of Gatsibo district. The research study was taken place from the month of January 2015 and is continuing up to date. However, due to time, personnel and budget constraints the geographical scope of the study was limited to a single district namely Gtsibo. To get significant feature of maize production from the farmers, questionnaires, interviews and observation were used as acceptable research instruments to fulfill desired information.

1.7 Limitation of the study

The study was limited mainly by geographical location of zones that are generally far from the main road (tarmac road). The researcher took a long time than estimated because respondents were busy in their farm. The study was limited in terms of the willingness of the respondents to participate in the study. In some households, the researcher had to be accompanied by local authorities to assure that all the information provided would be treated only for the academic purpose. Language was also enough barrier to respondents because the local language was Kinyarwanda. Therefore, here the time was mainly spent in reading, interpreting and translating questions to the participants in their local language.

CHAPTER TWO:

LITERATURE REVIEW

2.1 Theoretical literature review

This study adopted the theory of Production. A production function is a model used to find out the relationship between variables both independents and dependent one. The specification of the economic production function model was presented as follow below:

$$Y=f(L, S, F...) \dots\dots\dots (1)$$

Where Y represent a firms output, L may represent the amount of labor, S represents quantity of seeds used in production of Y while F represent the amount of fertilizers applied. The production function shows the maximum amount of the good that can be produced using alternative combinations of labor (L), seed (S) and fertilizer (F). Y is also referred to as the total physical product (TPP). This production relationship can be expressed in Cobb-Douglas functional form. The marginal physical product (MPP) of an input is the additional output that can be produced by employing one more unit of that input while holding all other inputs constant.

Where:

$$\text{MPP of labor, } MP_L = \frac{\partial Q}{\partial L} = f_L, \text{ Therefore, the second derivative is less than zero:}$$

$$\frac{\partial MP_L}{\partial L} = \frac{\partial^2 q}{\partial L^2} = f_{LL} < 0 \dots\dots\dots (2)$$

The average physical product (APP) is a measure of efficiency. The APP depends on the level of other inputs employed.

$$AP_L = \frac{\text{Output}}{\text{Labor}} = \frac{Q}{L} = \frac{f(F, L, S)}{L} \dots\dots\dots (3)$$

The concept of returns to scale shows how output responds to increase in all inputs together. Returns to scale can be either constant, decreasing or increasing. The elasticity of supply of an input measures how an output responds to changes in inputs. Production theory is the study of production, or the economic process of converting inputs into outputs.

A production function as purely the technical relationship between the physical inputs and output. It describes the laws of proportion, represent the technology of the firm and include all the technically efficient methods of production (Kontsoyians, 1979). According to Jhingan (2007), a production function expresses a functional relationship between quantities of inputs and outputs. It shows how and to what extent output changes with variation in inputs during a specified period.

The productivity measurement involves the use of basic concepts such as Average product (AP), Marginal Product (MP), Marginal Rate of Substitution (MRS), Elasticity of production (EP) and Returns to scale (RTS). The three stages of production are studied using these concepts. The production function consists of different functional forms. These include the Cobb Douglas, which is often used by researchers due to its simplicity and flexibility, linear, quadratic polynomials and square root polynomials. The law of diminishing marginal returns was introduced. Marginal & average physical product concepts were developed to achieve the objectives of this study (Olujenyo, 2010).

The rules of calculus for determining if a function is at a maximum or minimum were outlined, using a total physical product & marginal physical product concepts to illustrate the application. Finally, the concept of an elasticity of production was introduced, and the elasticity of production was linked to the marginal and average product function.

The production was defined as the processes and methods employed to transform tangible factors/resources or inputs (raw materials; semi-finished goods; or

subassemblies) and intangible inputs (ideas, information, and knowledge) into goods and services or output (Oluwatayo *et al.*, 2008). These resources can be organized into a farm or producing unit whose ultimate objectives may be profit maximization, output maximization, cost minimization or utility maximization or a combination of the four (Oluwatayo *et al.*, 2008). Certain parameters (Price taker and price maker) have to be known for one to understand how farmers make their decisions that enable them to attain their goals. This will enable a farmer to decide on what price to charge and to overcome the problems related to Food security, Profit maximization and finally Risk reduction. Because of agricultural produce that are usually perishable especially during season. Many primary markets are subject to extreme fluctuations in price. There are several methods of intervention available to governments and agencies. Buffer stocks should help stabilize prices by taking surplus output and putting it into a store, or, with a bad harvest, stock is released from storage.

The basic theory of production is thus simply an application of constrained optimization. The farm-unit attempts either to minimize the cost of producing a given level of output or maximize the output attainable with a given level of costs (Oluwatayo *et al.*; 2008). Cobb Douglas function has been used to estimate the relationship between inputs and outputs. Factor -Product relationship guides the producer in making the decision how much to produce. The Cobb-Douglas production function was used to estimate the stochastic frontier production function. This functional form was chosen because it is flexible, self-dual and its returns to scale are easily interpreted (Bravo-Ureta and Evenson, 1994). In addition, empirically, the Cobb-Douglas production function has been widely used in technical efficiency estimation (Hasssan *et al.*, 2005; Essilfie *et al.*, 2011).

The production function of any farmer is determined by resource availability of the farmer. A production may be defined as a mathematical equation showing the maximum amount of output that can be realized the Cobb-Douglas production function is given by:

$$Y = AL^{\beta}K^{\alpha}$$

Where:

Y = total production (the monetary value of all goods produced in a year) or quantity

L= labor input

K = capital input

A = total factor productivity

Where α and β are the output elasticities of labor and capital, respectively. These values are constants determined by available technology. Returns to scale refers to a technical property of production that examines changes in output subsequent to a proportional change in all inputs (where all inputs increase by a constant factor). If output increases by that same proportional change then there are constant returns to scale, sometimes referred to simply as returns to scale. If output increases by less than that proportional change, there are decreasing returns to scale. If output increases by more than that proportion, there are increasing returns to scale Doll, *et al.*;(1984) optimization of production is the goal of this relationship.

The sum of α and β indicates the nature of returns to scale, Upton (1979) observed that, the Cobb-Douglas production function cannot show both increasing and diminishing marginal productivity in a single response curve and as a result it does not give a technical optimum and may lead to the over estimation of the economic optimum. It can also provide a means of obtaining coefficients for testing hypotheses (Cobb and Douglas 1928; & Erhabor, 1982). While commenting on the superiority of Cobb-Douglas production function over other forms of production functions. Cobb-Douglas production function is used more than the other two because it satisfies the economic, statistical and econometric criteria of many studies than others. (Debertin 1986; Heady & Dillon 1972)

the relationship between the level of variable input and level of output can be illustrated with a production function.

The estimation of relationship between factor-product is measured by the elasticity of production. The elasticity of production is a concept that measures the degree of responsiveness between output and input. It is independent of the units of measurement.

$$Ep = \frac{\% \text{ change in outputs}}{\% \text{ change in inputs}} \text{ or } Ep = \frac{\Delta y / Y}{\Delta x / X} = \frac{\Delta y / \Delta X}{Y / X} = \frac{MPP}{APP} \dots\dots\dots (4)$$

$Ep = 1$, Constant Returns. Ep is one at $MPP = APP$ (At the end of I stage)

$Ep > 1$, Increasing Returns (I Stage of Production)

$0 \leq Ep \leq 1$, Diminishing returns (II Stage of Production) while Ep is negative in stage III.

According to Farrel (1957), the elasticity of production, which is the percentage change in output as a ratio of a percentage change in input, is used to calculate the rate of return to scale which is a measure of a firm's success in producing maximum output from a set of input. Different models were estimated in this study.

The determination of production elasticity becomes necessary for the estimation of responsiveness of yield to inputs. Output elasticity for each of the inputs calculated at the variable means is of great importance in this case Awudu and Eberlin (2001). The elasticity of output with respect to the Using Equation (5), output elasticity with respect to input, X_1 evaluated at the sample mean can thus be computed from the following Equation:

$$e_{X1} = \frac{dLnY}{dLnX1} = \beta_1 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3 + \beta_n LnX + \varepsilon \dots\dots\dots (5)$$

The elasticity of output with respect to the number of input measures the responsiveness of output to a 1% change in the number input. The measure of returns to scale, RTS

representing the percentage change in output due to a proportional change in use of all inputs, is estimated as the sum of output elasticities for all inputs Brayton, G. N. (1983). If this estimate is greater than, equal to, or less than one, we have increasing, constant, or decreasing returns to scale respectively:

$E_p > 1$, Increasing Returns (I Stage of Production)

$E_p = 1$, Constant Returns. E_p is one at $MPP = APP$ (At the end of I stage)

$E_p < 1$, Diminishing returns (II Stage of Production)

This relationship helps the producer in the determination of optimum input to optimum output and us to produce. Price ratio is the choice indicator. This relationship is explained by the law of diminishing returns. This law state that when increasing quantity of a variable input are used together with a fixed input eventually total product, average product and marginal products diminish.

According to Ekpebu (2002), there are many functional forms that could be used to describe production relationships like Cobb Douglas, quadratic, translog and transcensantal forms. However, in this study, the production function used was Cobb-Douglas. The really reason why the specified Cobb-Douglas production function was used was its ease of interpretation of returns to scale (Mushunje, 2005). The function is homogeneous of degree, $a+b$. If $a+b$ exceeds unity, there are increasing returns to scale; when $a+b=1$ there is constant returns to scale, and $a+b<1$ indicates diminishing returns to scale (Mushunje, 2005)

2.2 Empirical Studies on Productivity and Efficiency

Efficiency and productivity are very similar and cooperating concepts but not equal even though, in the efficiency literature many authors do not make any difference them. For instance, Sengupta *et al.*, (1995) defined both productivity and efficiency as the ratio between output and input.

Production efficiency mean attainment of a production goal without waste (Ajibefun & Daramola, 1999), while efficiency is concerned with the relative performance of the processes used in transforming given inputs into output (Onyenweaku *et al.*,2005). Efficiency is at the heart of agricultural production because the scope of agricultural production can be expanded and sustained by farmers through efficient use of resources. For these reasons, efficiency has remained an important subject of empirical investigation particularly in developing economies where majority of farmers are resource poor. Productivity of a production unit can be measured by the ratio of its output to its input. However, productivity varies according to differences in production technology, production process and differences in the environment in which production occurs. Producers are efficient if they have produced, as much as possible with the inputs they have actually employed and if they have produced that output at minimum cost (Lovell,1993).

Most often, different studies use the terms productivity and efficiency interchangeably, though they are not exactly the same. Productivity refers to the ratio of output(s) to input(s) while; efficiency is the highest productivity level from each input level (Coelli & Rao, 1998). Farrell (1957) classified efficiency as technical (physical), allocative (price) and economic (overall) efficiency. Technical efficiency shows the ability of farmers to produce maximum amount of output using the existing level of inputs. On the other hand, allocative efficiency measures the ability of farmers to use inputs in an optimal proportion, given the price of inputs and outputs. A firm is economically (overall) efficient if it achieves both technical and allocative efficiencies.

2.3 Empirical Studies on Productivity approach

Estimation of production functions and technical efficiency is one of the most popular areas of research. In microeconomic theory, production is defined as the process of transforming inputs (raw materials) into outputs. A production function represents technological relationships between inputs and outputs. In particular, it shows the

maximum level of output the firm can produce combining the existing inputs (Besanko & Braeutigam, 2005).

Several studies have been done on agricultural production using the production function model to estimate the impact of various factors on output. The different causal factors can influence production by inducing changes in input use, or by causing changes in productivity. With the production function model, the factors that significantly influence productivity can be identified. These include production factors (Seeds, fertilizer, land size, pesticide, fungicide), social-economic factors (Age, gender, experience, education, marital status, family size and family income), and institutional factors (Market access, agricultural credit, group membership and, extension service).

The measurement of agricultural productivity has remained an area of important research both in the developing and developed countries. This is especially important in developing countries, where resources are scarce and opportunities for developing and adopting better technologies are dwindling. Efficiency measures are important because it is a factor for productivity growth.

The study by Karanja, *et al.*, (1998), a Tobit model was used and two stage least squares to model maize productivity and adoption of technologies. Others concluded that maize productivity increased with fertilizer use, proximity to navigable roads, education, extension and the presence of a male in the household.

The collection of all available techniques is described by a production function or indirectly by a cost or profit function. Maize production is also about combining inputs to produce output. Studies conducted either in different areas have identified several factors affecting maize production. Some of these studies are reviewed in this section. In Africa, maize is the most widely grown staple crop and is rapidly expanding to Asia. Maize is vital for global food security and poverty reduction.

Most of these studies concentrated on cereals and very few on tuber crops. Using ordinary least square (OLS) criterion, Olujeny in the study of determinants of agricultural production reported that age, education, labour and cost of non-labour inputs were positively related to output with labor input having significant influence on output, while farm size, years of experience and sex showed inverse relationship with output. The study further revealed that maize farming was profitable. For example, the nearness to the market, group membership, and credit-access and extension service are hypothesized to have a positive influence on maize production efficiency. This is because nearness to the market increases access to inputs and credit. While group membership is expected to help farmers to mitigate problems associated with market imperfections.

On the other hand, credit access provides funds necessary for farmers to overcome liquidity problems that hinder them from purchasing inputs on time. Then access to extension service provides farmers with information on better methods of farming and improved technologies that improve their productivity. With respect to socio-economic characteristics of the farmer, it is hypothesized that age of the farmer negatively affects production efficiency. This is because older farmers are risk averse making them late adopters of better agricultural technologies. Gender of the farmer is also supposed to have a negative relationship because female farmers are faced with more challenges compared to the male farmers in terms of access to information and resources.

Similarly, farmers whose main occupation is farming are expected to have lower efficiency than those engaging in employment or businesses as well. This is because the latter are abler to finance their farming activities. Off-farm income is expected to have a positive effect on production efficiency; since farmers with such incomes have a regular source of income that they can use to acquire farm inputs. Farmer's experience is expected to positively influence production efficiency because experienced farmers are better producers, who have learned from their past mistakes; hence they make rational decisions compared to less experienced farmers.

Due to the increasing demand for feed and bio-energy, the demand for maize is growing and is expected to double by 2050 (Rosegrant *et al.*, 2007). Unfortunately for many farmers in Africa, maize yields (output per acre) have fallen in the last decade, in spite of improvements in agricultural technologies (Saari 2011). Among the major factors affecting yields are the production environment, production systems, seed varieties and other production inputs and financial outlays on research.

The studies like Seidu (2008) which emphasize those large households are better in providing free labor, indicating the usefulness of larger households in improving farm efficiency. In fact, 60 percent of the total maize area in the developing world, outside of Argentina, Brazil & China, is estimated to be still planted to unimproved, local varieties. Although national and international breeding programs have considerably increased the yields of open-pollinated varieties over the past, they remain below those of hybrids. Yields of hybrids, in fact, can exceed those of landraces open-pollinated varieties by 30-100 percent, with an average of perhaps 40-50 percent.

A study of comparative economic analysis of rice production found that farm size and fertilizer use were the significant determinants of output of rice (Abdullahi, 2012). Maize production involves so many activities and this has been source of employment among the women and youth within the society (MINAGRI, 2011). Farmers earn income through reaping of the output and this uplifts their living standards especially to the rural areas. Farming experience has also been found to affect farm output. Various authors have found that experience in farming enhances efficiency.

However, it is not only the people employed in agriculture who benefit from increases in agricultural productivity. Those employed in other sectors also enjoy lower food prices and a more stable food supply. It also supported by Jones *et al.*, (2007) found that the wages may also increase during seasonal good price. However, these studies fail to adequately answer the questions of factors such as improved seeds, fertilizer application

methods and markets price affect the increased maize output. This study tries to find out gaps in determination of factors influencing maize production in Gatsibo, Rwanda.

The main important factor that should or not increase maize production is the price. Producing maize should many refer to how much of a price of a product is given at a market. As with demand the quantity supplied depends on the price of the product and on the conditions of supply. If the price of a product is high, normally more of a product will be supplied (Fuglie *et al.*, 1999).

The efficiency simply means that as resources are scarce, they have to be used in an appropriate manner. This concerns the relationship between inputs and outputs (Meeusen, &Den Broeck, 1977). Using inputs efficiently will mean that costs will be reduced and that output will either remain the same or it will increase. Hence, with lower costs it may be possible to keep either output the same or even increase output. The main point in efficiency is getting more from less. Factors that influence productivity may be depend on the quantity and quality of inputs used including fertilizer, seeds farm and farmer characteristics and external factors such as government policy (Wiebe,, 2001).

In order to identify different factors influencing the achievement of optimum output of maize in study area a Tobit regression model was taken into consideration. James Tobin, the Nobel laureate economist (Gujarati, 2004), originally developed this model. It has been applied in several empirical studies of adoption (Shakya & Flinn, 1985; Adesina & Zinnah, 1993).

The ,credit is necessary for improved maize farming associations running collection centers, buying products from producers and selling on in bulk. However, significant financial assets are not essential for maize farming at subsistence level (Bourdieu 1984). A good maize farming project will work to ensure that all available capital assets are taken into consideration, without dependence on any that are not. (Olujeny 2008) applied the qualitative approach to evaluate the performance of improved maize varieties in Ghana, under the grains development project. They found that improved maize

varieties significantly increased yields for farmers switching from local varieties. Other studies including Adesina and Baidu-Forson (1995) used Tobit model to study modern sorghum and rice varietal characteristics and showed that farmer perceptions of technology characteristics significantly affect adoption decisions of those new agricultural technologies.

According to the study of De Groote *et al.*, (2005) using an econometric approach, analyzed the maize green revolution in Kenya using farm level surveys between 1992 and 2002. They found that intensity of fertilizer use had a major effect on maize yield. There are some of the activities, which end up affecting maize production positively, and negatively in the region, for example sugar farming where the land used in maize production is being replaced thus the decline in maize production. Production theory states that under competitive conditions, a firm is said to be efficient if it equates the marginal returns of factor inputs to the market price of the input (Fan, 1999). Farmers are required to take their produce to a group collection centre and contact the buyer for collection. The group members are given priority than non-group members though the collection centre do not reject to collect from non-members.

Dercon and Christiaensen (2007) found that poor harvest and subsequently low consumption could lead to low fertilizer application in Ethiopia. The results are similar to those of neighboring Kenya, where adoption patterns also vary from season to season. Duflo *et al.*, (2008) sought to understand the returns to fertilizer and reasons for low fertilizer application in Western Kenya using experiments. They found dismal learning effects and a rate of return to top dressing fertilizer of between 52% and 85%. In addition, they initiated a Savings and Fertilizer Initiative (SAFI), which offered farmers subsidized fertilizer at harvest time as opposed to planting time. They reported an 11-14% increase in adoption.

De Groote *et al.*, (2005), using an econometric approach, analyzed the maize green revolution in Kenya using farm level surveys between 1992 and 2002. They found that

intensity of fertilizer use had a major effect on maize yield. However, the use of improved maize varieties did not have any effects on the yields, an indication that some local varieties could perform as well as the improved varieties in some areas

When the right type of fertilizer for a given crop is used in recommended quantities at the right time, fertilizers do generally not harm the environment otherwise increase productivity of crops. Saari (2011) saw that Fertilizers also have numerous positive impacts on the environment some of them direct others indirect. Positive impacts include improvement of farming efficiency for example maize production levels in Ngoma for one season. The production is respectively without fertilizer 3tonnes 150kgs/ha, use compost 4tonnes 525Kgs/ha, both organic and Inorganic 7tonnes 875kg/ha, Inorganic only DAP and UREA 5tonnes 350Kgs/ha. Morris *et al.*,(1999) found that the use of fertilizer alone increased yields significantly, even where the farmers planted local maize varieties.

The increased use of inorganic fertilizers resulted in the production of healthier crops with increased crop cover and increased biomass production crop residues, which in turn reduces soil erosion and contributes to building-up soil organic matter levels, increasing water holding capacity and microbial activity, leading to prevention of soil degradation; Reduced area under cultivation because of higher yields as a result of fertilizer use and thus production of food needs that would be met with reduced cultivated areas at various levels from the household, community, regional and national levels (Waithaka *et al.*,2007).

The main limitation of the study is that it relied on recollections by farmers who had switched from one variety to another. This may reduce the reliability of the results, especially for farmers facing multiple scenarios. Marennya & Barrett (2009) indicated that, in an interesting study of fertilizer interventions in Western Kenya, found that fertilizer application is beneficial to farmers with high soil organic matter. The implication is that plots with poor, degraded soils limit the marginal productivity of

fertilizer. The finding showed that farmer used both combination of chemical and organic fertilizer gained more that those who do not use any type of fertilizers. However, as recommendations farmer should use fertilizer (quantity) recommended and on time as well as during planting and for top dressing.

2.4 Empirical studies on Efficiency

Efficiency is a very important factor of productivity growth, especially in developing agricultural economies where resources are meager and opportunities for developing and adopting better technologies are dwindling (Ali & Chaudhry, 1990). The efficiency of a production unit in terms of a comparison between observed and optimal values of its output and input (Lovell 2000). The comparison can take the form of the ratio of observed to maximum potential output obtainable from the given input, to observed input required to produce the given output. For this study, three efficiencies such as allocative, economic and technical efficiency were used.

Allocative efficiency measures the distance between the farm and the point of maximum profitability, given market prices of inputs and outputs. In other words, the allocative efficiency shows whether the use of different proportions of production factors guarantees the attainment of maximum production with a particular market price (Forsund *et al.*, 1980).

Technical efficiency may be defined as the ability of a firm to produce as much output as possible with a specified level of inputs, given the existing technology. Technical efficiency is measured as the ratio between the observed output and the maximum output, under the assumption of fixed input, or, alternatively, as the ratio between the observed input and the minimum input under the assumption of fixed output (Porcelli, 2009).

Economic efficiency is the ability of farmers to maximize profit and is described as the product of technical and allocative efficiency (Adeniji, 1988). It indicates the costs per unit of output for a firm which perfectly attains both technical and price efficiencies. The

cost function approach combines the concepts of technical and allocative efficiency in the cost relationship. Technical and allocative efficiencies are necessary and when they occur together, are sufficient conditions for achieving economic efficiency (Adeniji, 1988).

There are four major approaches to measuring efficiency (Coelli *et al.*, 1998). These are the non-parametric programming approach, the parametric programming approach, the deterministic statistical approach and finally the stochastic frontier approach. Among these four approaches two of them especially the stochastic frontier and non-parametric programming were used in the study of economics analysis of the factors influencing maize productivity efficiency among farmers in Gatsibo district, Rwanda.

The stochastic frontier approach is preferred for assessing efficiency in agriculture because of the inherent stochasticity involved (Coelli, 1994). This study estimates the level of efficiency and its determinants in maize production in eastern province of Rwanda using the Cobb-Douglas stochastic frontier cost function approach.

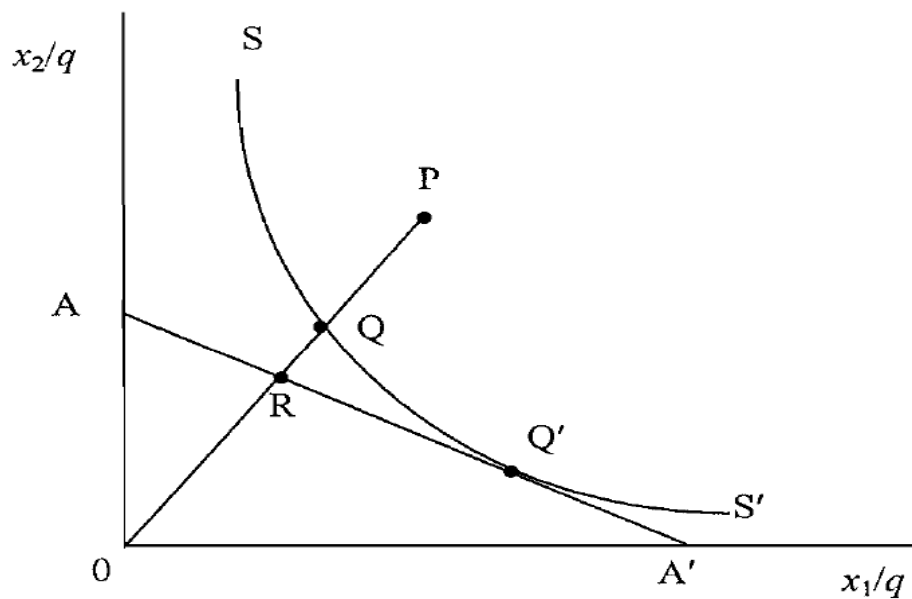


Figure 2 1: Graphical representation of Technical and allocative efficiencies

Thus, the technical efficiency of a firm is one minus the ratio of PQP_0 as shown in equation (2). On the other hand, allocative efficiency is measured by the ratio of input prices represented by the slope of isocost line AA' , whereas economic (overall efficiency) is the product of technical and allocative efficiencies (Coelli, *et al.*, 2005).

This is usually expressed in percentage terms by the ratio of QP/OP , which represents the percentage by which all inputs need to be reduced to achieve technically efficient production.

$$\text{Technical efficiency TE} = (OQ/OP) = 1 - (OP/OP) \dots \dots \dots (1)$$

$$\text{Allocative efficiency AE} = (OR/OQ) \dots \dots \dots (2)$$

$$\text{Economic efficiency EE} = \text{TE} * \text{AE} = (OQ/OP) * (OR/OQ) = (OR/OP) \dots \dots \dots (3)$$

2.4.1 Empirical studies on factors influencing technical efficiency

Technical efficiency may be defined as the ability of a firm to produce as much output as possible with a specified level of inputs, given the existing technology. Technical efficiency is measured as the ratio between the observed output and the maximum output, under the assumption of fixed input, or, alternatively, as the ratio between the observed input and the minimum input under the assumption of fixed output (Porcelli, 2009).

In this study, a technical efficiency is the ability of a maize farm to produce the maximum possible yield per unit area using a minimum combination of farm resources and using improved maize varieties.

A number of studies have been carried out to determine factors that influence efficiency of farmers especially on rice. (Farrel's, 1957) pioneer work on production efficiency that assumed constant returns to scale has been under going further improvements to increase the power of estimation (Ogundele & Okoruwa, 2006). Further modification of measurement went on to include other factors that were presumed to affect efficiency.

In his study Kinde (2005) analyzed TE to identify principal factors that cause efficiency differentials among maize producing farmers in Assosa district. The author used a cross sectional data collected in 2003/2004 production year for a total sample size of 120 households in the district. According to his findings, there was wide variability in the efficiency level of farmers, and the majority of the farmers attained efficiency levels of more than the average efficiency level.

The key determinants of technical efficiency take two broad categories: (1) Human capital, which Comprises age, sex, education, and experience in farming; and (2) socio-economic factors that comprise credit availability, extension services, off-farm income, tenancy status, labour type, firm size among others Birungi *et al.*,(n.d.).

Most empirical studies on productivity and efficiency of farmers indicated that demographic, socio-economic, institutional, environmental and resource factors are the major determinants of efficiency differentials among farmers (Battese & Coelli, 1995; Bravo-Ureta & Pinheiro, 1997; Obwona, 2006; Nyagaka *et al.*, 2010).

For example, in their analysis on technical efficiency of smallholder farmers in Girawa district of Ethiopia, Ahmed *et al.*,(2013) confirmed that technical efficiency of farmers is positively associated with education, extension services, livestock holdings and use of irrigation. Thus, education and extension services increases efficiency of a farmer by increasing awareness and ability on the proper use of farm inputs control of pest and crop diseases and overall management of farm productions.

Bagamba *et al.*, (2007) analysed the technical efficiency of banana production among Ugandan smallholders by using the SFA approach. They examined banana productivity with specific focus on two constraints, soil fertility and labour. Contrary to many studies, the findings revealed that proximity to the market gave mixed results. Bagamba argued that proximity to the market could either increase farmers' ability to access credit, which enables them to buy and apply inputs.

Elias and Zubaidur (2012) in their study of the technical efficiency of rice farmers in Bangladesh, Naogaon District, and the result indicated that technical inefficiency is influenced negatively by the age, education, experience, agriculture policy, rice monoculture and use of high yielding variety variety of seeds whereas the same were influenced positively by the farm size.

Thong *et al.*, (2014) investigated the factors affecting technical efficiency of smallholder coffee farming in the Krong Ana Watershed, Vietnam, and concluded that formal education of the household head, the amount of financial credit obtained, ethnicity, coffee farming experience of the household head, and agricultural extension service used were key factors that can increase technical efficiency in coffee production.

Fekadu (2004) also analyzed the TE of wheat producing farmers of Machakel district in east Gojjam zone of Amhara regional state using cross-sectional data collected in 2003 production year. The Cobb-Douglas type production function was used to estimate the efficiency of smallholder wheat producers in the area. He revealed from the estimated SPF model that, area of the plot, amount of DAP and Urea fertilizers, and amounts of seed were significant determinants of production level.

Tchale (2009) indicated that the size of land holding (farm size) inversely influence technical efficiency contrary to findings by Croppenstedt (2005) and Fernandez *et al.* (2009), and implies that as the land holding increases it becomes more involving to manage it; hence the efficiency level decreases.

In their analysis on technical efficiency of smallholder farmers in Girawa district of Ethiopia, Ahmed, *et al.* (2013) confirmed that technical efficiency of farmers is positively associated with education, extension services, livestock holdings and use of irrigation. Thus, education and extension services increases efficiency of a farmer by increasing awareness and ability on the proper use of farm inputs control of pest and crop diseases and overall management of farm productions.

2.4.2 Empirical studies on factors influencing allocative efficiency

Production theory states that under competitive conditions, a firm is said to be allocative efficient if it equates the marginal returns of factor inputs to the market price of the input (Fan, 1999). Allocative efficiency also is defined as measures of the distance between the farm and the point of maximum profitability, given market prices of inputs and outputs. In other words, the allocative efficiency shows whether the use of different proportions of production factors guarantees the attainment of maximum production with a particular market price (Forsund *et al.*, 1980).

By considering different definitions, several of studies have been conducted on the determinants of allocative efficiency. Allocative efficiency indicating the ability to optimize the use of inputs in various proportions giving their respective prices. This study borrows the definition of allocative efficiency from. (Tijani 2006) as the ability of a maize farmer to choose and employ the inputs in maize production to that level where their marginal returns equal their factor prices.

Ugwumba (2010) used the parametric and non-parametric statistics to investigate the allocative efficiency of 'egusi' melon production inputs in Owerri West Local Government Area of Imo State, Nigeria. The results of data analysis showed household size, cost of inputs and farm size as significant determinants of production output. Production output was also positively influenced by land, labour (family and hired), and fertilizer, capital and seed inputs. More so, computed allocative efficiency values showed that land (1.14), fertilizer (17.44) and seed (1.76) inputs were underutilized while family labour (0.64), hired labour (0.08) and capital (0.83) inputs were over utilized.

Laha and Kuri (2011) measured allocative efficiency and its determinants in agriculture practiced in West Bengal by implementing the cost minimization principle using Data Envelopment Analysis. The variable that was found to play a significant role in influencing allocative efficiency was the choice of tenurial contracts. Among the tenurial

contracts, fixed rent tenancy was observed to be the most efficient mode of cultivation. The household head's level of education, operated land, inter-linkage of factor markets and availability of credit facilities were some of the other factors, which were found to have significant bearing on the level of allocative efficiency in West Bengal agriculture.

A study by Nwachukwu and Onyenweaku (2007) on allocative efficiency among pumpkin farmers in Nigeria, using a stochastic frontier approach, found that the farming experience had a positive effect on allocative efficiency. The authors observed that farmers' wealth of experience in pumpkin farming made them able to allocate their resources more efficiently.

Lopez (2008) also conducted a study on Kansas farms in the USA. The study applied a DEA & Tobit methodology used by many other authors to measure technical, allocative, scale and overall efficiencies and their determinants. According to her findings, off-farm income had a positive effect on allocative efficiency.

Education of the household head has also been found to significantly affect allocative efficiency. According to a study by Laha and Kuri (2011) in India, farmers' years of schooling was found to have a positive effect on allocative efficiency; suggesting that the more years a farmer had spent in school the more able he was to efficiently allocate his farm resources.

According to credit, Obare *et al.* (2010) found a positive influence on allocative efficiency. They observed that farmers with ease of access to credit exhibited higher levels of allocative efficiency. According to the authors, credit availability is expected to limit constraints hindering timely purchases of inputs and engagement of farm resources.

Obare *et al.* (2010) in his study on of the farmers' group membership argue that farmers who are affiliated to producer associations are bound to have more allocative efficiency. This finding is similar to that by Tchale (2009) on crop farmers in Malawi. According to

Obare and others, producers form groups to pool resources together so as to mitigate the consequences of market imperfections.

Laha and Kuri (2011) in their study on allocative efficiency in India. Indicated that allocative efficiency is also influenced by interlinkage in the factor markets, In their findings, there was a positive relationship between factor market interlinkages and allocative efficiency.

Obare *et al.* (2010) in his study observed that regular visits of extension workers positively influenced a farmer's allocative efficiency. This is attributed to the fact that the knowledge gained from extension visits influences producers to adopt new technologies through which they become more efficient.

2.4.3 Empirical studies on factors influencing economic efficiency

It is used to mean the ability of a maize farmer to employ a cost minimizing combination of farm inputs and at the same time producing the maximum possible output, given the available technology. (Bravo-Ureta & Pinheiro 1997) in their analysis of economic efficiency in the Dominican Republic found that education had a negative effect on economic efficiency. This suggests that educated farmers in the Dominican Republic were less efficient economically, compared to their uneducated counterparts. Therefore, schooling can influence overall efficiency either positively or negatively.

Mulwa *et al.*, (2009) in western Kenya observed that farming experience had a positive influence on economic efficiency. Mbanasor & Kalu (2008) also found similar results for vegetable farmers in Nigeria, which coincides with their findings for age. It is expected that experienced farmers have over the years learned from their mistakes and improved their efficiency in production. Nyagaka *et al.*, (2009) further found a positive effect between extension visits and economic efficiency. This is consistent with findings (Mbanasor & Kalu., 2008) and implies that the more extension visits a farmer accessed from the extension workers; the more economically efficient he became. Improving the productivity of maize-based farming could significantly reduce hunger, enhance food

security and alleviate poverty through increasing the purchasing power of the farmers. Laborers therefore have more money to spend on food as well as other products.

Nyagaka *et al.* (2009) in his study on Irish potato producers in Kenya, farmer's education positively influenced farm economic efficiency. It was argued that farmers with higher levels of education were more efficient in production and this was attributed to the fact that educated farmers positively perceive, interpret and respond to new technologies on seeds, fertilizer, pesticides, fungicides, herbicides or markets much faster than their counterparts respond.

Bravo-Ureta & Pinheiro (1997) in his study on the effect of age on economic efficiency found that age of the farmer had a negative effect on economic efficiency due to the categories. The authors categorized age into young farmers and older farmers, with a dummy. It was therefore observed that young farmers below the age of 20 were more economic efficient than older farmers in the study area.

Farming experience has also been found to affect farm overall efficiency. Various authors have found that experience in farming enhances efficiency. Mulwa *et al.* (2009) in western Kenya observed that farming experience had a positive influence on economic efficiency.

Extension services have been found to have a positive effect on economic efficiency. Nyagaka *et al.* (2009) in their study found a positive effect between extension visits and economic efficiency. This is consistent with findings by Mbanasor efficient he became.

According to credit, Ceyhan & Hazneci (2010) analysed cattle farms in Turkey and found a positive relationship between credit and economic efficiency. It therefore reaffirms the observation by Nwachukwu & Onyenweaku (2007) in Nigeria that although credit helps solve liquidity problems in input access, difficulties in accessing such funds for farming is responsible for the negative effect, and is a common phenomenon for most of the African farmers.

2.5 Conceptual Framework of the study

Productivity is some of the basic concept in economics of agricultural production. Agricultural productivity is synonymous with resource productivity, which is the ratio of total output to the resource or inputs used. Maize productivity in general may be increased through different ways. First, best way to enhance maize productivity is through improving efficiency of resource utilization. The conceptual framework of this study is effectively shown in Figure 2 below, which indicating how various factors inter-relate to influence maize productivity in study area. For this study the factors of maize productivity were grouped into three main classes namely Production Factors as first class composed of Land size ,improved Seeds, chemical fertilizer, organic fertilizer, pesticide and fungicide. Social-economic Factors as second class composed of age, gender, experience, education, marital status family size and family income and the third class called Institutional factors currently composed of agricultural credit, access to market, extension service and group membership. The availability and efficiency use of these inputs may influenced maize productivity. It is expected that the more inputs used by the farmer in proper manner, the higher maize yields per unit area. Although, for chemical inputs, increased usage. A farm that is technically, allocatively and economically efficient is therefore expected to realize higher maize output per hectare compared to one that is less efficient in production.

CONCEPTUAL FRAMEWORK

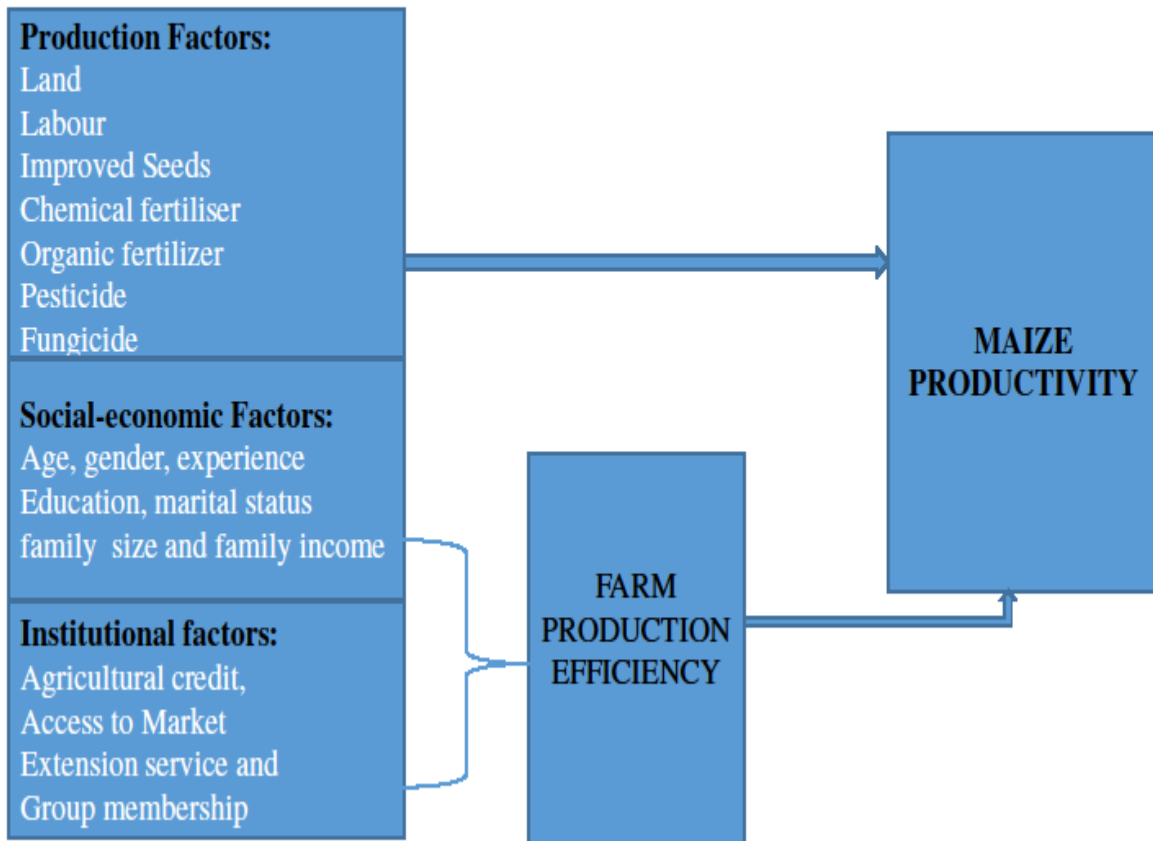


Figure 2 2: conceptual framework of the study

2.6 The overview/Synthesis of Literature

This section presents a brief review of the literature on the analysis of productivity efficiency and the farm towards household specific factors that affect technical, economic and allocative efficiency among farms in Gatsibo, Rwanda. Technical

efficiency and allocative efficiency are two main indicators that are widely used to provide a rigorous measure of the efficiency of production of a unit/farm. Empirical studies that measured the efficiency of production of a particular crop, especially maize are quite few in Rwanda. Despite efforts in various studies that analyzed the efficiency of maize production in eastern Rwanda, there is limited studies attempted to consider the efficiency of maize production in this agro ecological zones. This study is the first regional scale study measuring technical efficiency of maize across 7 agro ecological zones (ABIFATANJE, DUKANGUKE, ISONGA, UBUHORO, INDATEZUKA, SHIKAMUKORE, & INDUSHABANDI) of Gatsibo district of Rwanda. Attempt was also made to identify various socio-economic factors that determines technical efficiency in the area. The result of this study is expected to identify States with low level of efficiency with a view to suggesting measures aimed at improving maize production efficiency. Against this background, the main purpose of this study is to determine the technical efficiency of maize production in Eastern Rwanda. The study also intend to identify factors that could explain technical efficiency among the respondents.

CHAPTER THREE:

RESEARCH METHODOLOGY

3.1 Description of the study area

Gatsibo District is one of the seven Districts making the Eastern Province. It is divided into 14 Sectors. It is also divided into 69 cells and 603 villages “Imidugudu”. Spreading an area of 1585, 3 km². The District borders with the Akagera National Park in East, to the North by Nyagatare District; to the West by Gicumbi District, to the South by Rwamagana & Kayonza Districts. (www.gatsibo.gov.rw) accessed 5th February 2013

The total population of Gatsibo District increased from 283,456 in 2002 to 433,997 in 2012. Gatsibo District has population density of 275 persons per square kilometer. The increase in the population represents a growth rate of 53.1% between 2002 and 2012. Males represent 48% of the population whereas females represent 52% of the population (NISR, 2012).

The relief of Gatsibo District is characterized by scarcely short hills and flat land separated by valleys in East, East, South East and North while the West and South West is characterized by high mountains in administrative sector of Nyagihanga, Kageyo, Gatsibo, Muhura, Gasange & Remera which are characterized by two principal seasons: a long dry season and rainy season.

In the lowlands (east and southwest), temperatures are higher and the extreme can go beyond 30°C in February and July-August (Twagiramungu 2006). The monthly average temperature at Kibungo (Eastern Province) stays between 20°C and 22°C throughout the year without any large fluctuations. The annual maximum temperature at Kibungo is about 29° C from March to April, and the minimum temperature is about 14°C from October to November. Gatsibo District is known of the low rainfall and high temperatures that limit the availability of water. The hydrography of Gatsibo District is largely constituted of streams and rivers such as; Walfu, Karungeri, Cyamuganga,

Kanyonyomba, Rwangingo, Kabahanga, Kagina, Kagende, Rwagitima & Ntende. Gatsibo District is located at 01°33'Latitude, 30°24' Longitude with Altitude of 1550m and annual rainfall until 1990mm (EICV 2, 2007).

Gatsibo District is characterized in general by lowly inclined hills and flat land separated by dry allies. The District is located in the granite low valley whose average altitude is 1550m spread on the plateau and the savannah of the Eastern part of the country. This kind of topographical layout constitutes an important potentiality for modern and mechanized agricultural farming. This relief offers to Gatsibo a vocation agro pastoral and tourism (www.gatsibo.gov.rw) accessed 5th February 2013

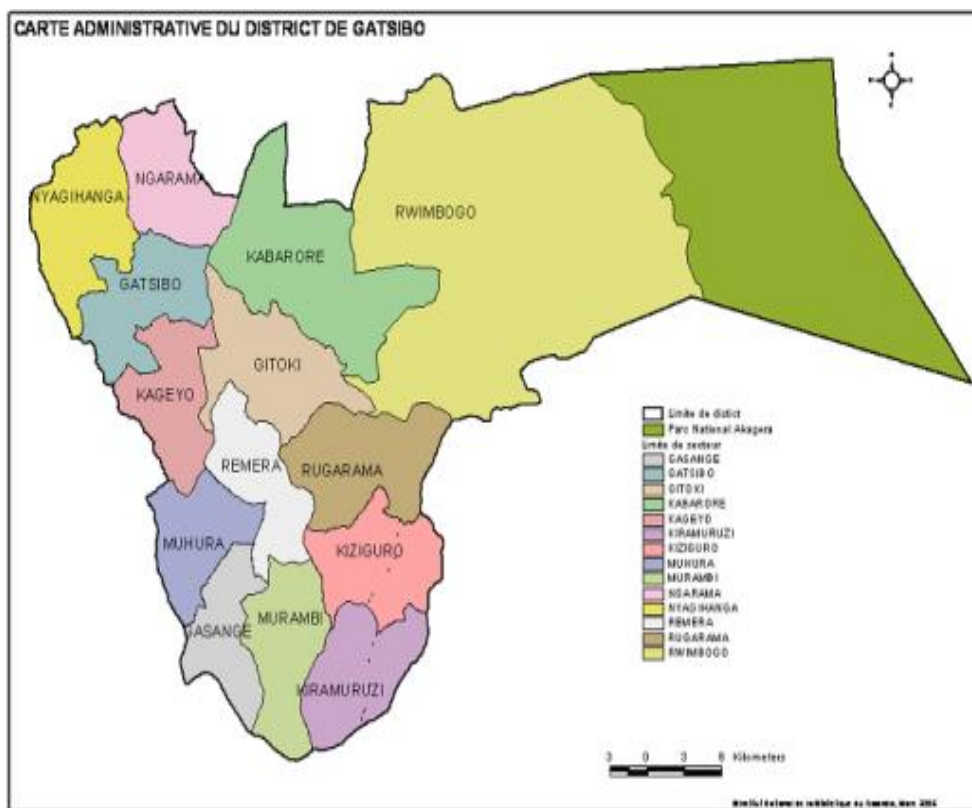


Figure 3 1: Gatsibo District map location of the study area

Source: NISR 2012, EICV 3 (Thematic Report on Gatsibo, 2012)

3.2 Research design

A cross-sectional survey using a questionnaire was conducted in Gatsibo district in Eastern province of Rwanda. The population constituted householder farmers of maize in Gatsibo district of Eastern province of Rwanda where a sampling unit was the farm household. For sampling purposes, a multistage sampling technique was used involving purposive sampling of one district in selected Eastern province and seven zones of farming in Gatsibo district. This was used because it involves a combination of some of the previous types of sampling. Then a simple random sampling procedure was used to select the sample size in each zone of farming.

3.3 Sample size and sampling technique

Gatsibo district was purposively selected for this research because of prevalence of maize producers in the area. Based on the list of cooperatives and individual farmers of maize obtained from the District agriculture office, a multi-stage sampling procedure was applied to the population of maize farmers from the area under study. In the first stage, seven zones of maize farming were purposively selected based on the intensity of maize production and in the study area. The zones include Abifatanije, Dukanguke, Indatezuka, Indushabandi Isonga, Shikamukore, & Ubohoro. Secondly, a community was randomly selected from each zone. In the second stage, a number of respondents of maize farmers were proportionally selected due its size to get a sample size of 168 respondents.

Table 3 1: Study population and sample size

Zone of farming	Sampling frame	Sample size
Abifatanije	60	29
Dukanguke	45	21
Indatezuka	43	20
Indushabandi	41	19
Isonga	50	24
Shikamukore	55	26
Ubuhero	60	29
TOTAL	354	168

3.4 Data collection procedure and pilot test

For this study, both primary and secondary data from different sources were used. The primary data on socio-economic variables such as demographic characteristics, extension services, credit access, price data, amount and cost of labour used, the amount and cost of inputs used such as seed and fertilizer and the amount of outputs obtained were collected using structured questionnaire which was administered by trained enumerators from July 2015. Before starting a full data collection, some preliminary information about the overall farming system of the district was assessed through informal survey. Pre-testing of the questionnaire was also conducted and appropriate refinements and modifications were made in the questionnaire.

The information obtained from the pre-test was used to revise the questionnaire to make it more focused and easier to administer. After incorporating the lessons learned from the pre-test, the questionnaire was ready for administration, and then full data collection has been conducted from 27 to 31 July 2015 in Gatsibo, Rwanda.

3.5 Data processing and analytical technique

The data collected from the sample households and other sources were analyzed using Descriptive statistics and econometric models. The data collected were socio-economic, institutional and demographic characteristics of the household. The first objective the study was attained by using descriptive statistics presented in tables of frequencies, percentages, standard deviation, and means. The second objective was attained by estimating allocative efficiency and technical efficiency using a Cobb Douglas production function and a stochastic production frontier function derived from a Cobb Douglas function respectively. The third objective was attained by estimating a logit linear regression model. In the econometric analyses, a stochastic frontier approach and a logit regression model were used to estimate the level of technical, allocative and economic efficiencies and the relation between farm level socio-economic and institutional variables. The descriptive statistics were run using (SPSS) version 20 while the empirical models were run using (STATA) version 13 software.

3.6 Specification of econometric models

3.6.1 Model specification for Allocative Efficiency

In this part, the estimation of allocative efficiency was done using a Cobb Douglas production function. This study assumes that maize productivity is the dependent variable, which currently depends on the explanatory variables such as land size of allocated on maize, amount of seed planted/sowed, human labour used, amount of fertilizers applied, and amount of pesticides applied. Therefore, allocative efficiency is estimated following physical production relationships derived from the Cobb – Douglas production function of Equation (1). Thus, the specific model estimated is presented as follow below.

$$Y = \beta_0 X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} u \dots \dots \dots (1)$$

Where:

Y= Total quantity of maize produced (Kg)

β_0 =Constant

u= random error

X1-X5 are the explanatory variables

β_1 - β_5 = Parameters to be estimated

X₁ = Land size allocated on maize (Ha);

X₂ = Amount of seed planted/sowed (Kg)

X₃ = Human labor used in maize production (person day)

X₄= Amount of fertilizers applied in maize production (kg)

X₅= Amount of organic manure applied in maize production (kg)

X₆= Amount of pesticides applied maize production (L)

From the equation (1), the linear production function was expressed as follow:

$$\ln Y = \ln \beta_0 + \sum_{i=1}^5 \beta_i \ln x_i + u \dots \dots \dots (2)$$

Where:

β_0 and β_i are parameters to be estimated. Following Chukwuji and his counterparts (2006), the allocative efficiency analysis is done by estimating a Cobb-Douglas function using OLS. It is followed by computing the value of marginal product (VMP) for each

factor of production, which then is compared with the marginal input cost (MIC). Results from (2) give (β_i) .

$$\frac{\partial \ln y}{\partial \ln x} = \frac{\frac{1}{y} \cdot \partial y}{\frac{1}{x} \cdot \partial X} = \frac{X}{Y} * \frac{\partial y}{\partial X} = \beta_i \dots \dots \dots (3)$$

Using the coefficient estimates from (3), the marginal product (MP) of the i^{th} factor X was calculated as follow:

$$MP_i = \frac{\partial y}{\partial X_i} = \beta_i \frac{Y}{X_i} \dots \dots \dots (4)$$

However,

$$AP = \frac{Y}{X_i}$$

Where:

Y is the geometrical mean of maize output

X_i is the geometrical mean of input i ; β_i is the OLS estimated coefficient of input i . The value of marginal product of input i (VMP_i) can be obtained by multiplying marginal physical product (MP_i) by the price of output (P_y). Hence,

$$VMP_i = MP_i * P_y \dots \dots \dots (5)$$

$$A.E = \frac{VMP_i}{P_i} \dots \dots \dots (6)$$

Where:

P_i = Marginal cost of the i^{th} input.

Allocative efficiency is determined by comparing the value of marginal product of input i (VMP_i) with the marginal factor cost (MIC_i). The point of allocative efficiency (maximum profit) is reached when $VMP_i = P_{xi}$ Chavas *et al.*, (2005).

3.6.2 Model specification for Technical Efficiency

Technical efficiency was estimated to achieve the second part of the second objective. Following (Battese 1992) & (Raham 2013), technical efficiency of maize production is estimated using a stochastic production frontier, which is specified as follow:

$$Y_i = f(X_i, \beta) e^{v_i} TE_i, (i=1, 2, \dots, n) \dots \dots \dots (7)$$

Where:

Y_i is output of i^{th} household;

X_i is vector of inputs used in the production process by i^{th} household;

$f(x; \beta)$ is production frontier;

β is a vector of frontier parameters to be estimated;

e^{v_i} is the measures of random shocks and finally;

TE_i is the technical efficiency of the i^{th} farm household.

Technical efficiency of an individual farm is the ratio of observed output to the corresponding frontier output Coelli *et al.*, (2005). Therefore, technical inefficiency measures the amount by which the actual level of output falls below the frontier level. The value of technical efficiency varies between zero and one. When the technical efficiency is exactly equal to one, the actual output achieves its potential level. On the other hand, if technical efficiency is less than one, it implies the presence of technical inefficiency.

Technical efficiency therefore can be represented as follow:

$$TE = \frac{Y_i}{f(X_i, \beta) e^{v_i}} \dots \dots \dots (8)$$

Where: $0 \leq TE_i \leq 1$

Most stochastic frontier studies use either a Cobb-Douglas (CD) or Translog (TL) functional form for the production functions. In this study, only CD model was specified and the most appropriate model is selected based on log-likelihood ratio tests. Considering the factors of production, the Cobb-Douglas stochastic production frontiers was specified directly as follows:

$$\ln(Y_i) = \ln \beta_0 + \beta_i \sum_{i=1}^5 \ln(X_i) + v_i - u_i \dots \dots \dots (9)$$

Where:

\ln is the natural logarithms;

β 's are coefficients of parameters to be estimated;

y_i is the total value output in study;

X 's are factors of production;

v_i is the idiosyncratic error that arises from measurement errors in input use and/or yield;

u_i is the non-negative random variables in measuring the technical inefficiency of individual household.

The non-negative error term u_i assumes different distributional forms. The most commonly used distributions are half-normal, exponential, truncated-normal, and gamma distributions. Each of these forms having its own assumptions and characteristics. The two components v and u are also assumed independent of each other.

The parameters are estimated by the maximum likelihood method following Bravo-Ureta & Pinheiro (1993) and Bi (2004). On the other hand, u_i is a *non-negative* truncated half normal, $N(0, \sigma_u^2)$ random variable associated with farm-specific factors, which leads to the i th firm not attaining maximum efficiency of production; u_i is associated with technical inefficiency of the farm and ranges between zero and one. Green (2005) outlines the Log likelihood estimation of the normal-truncated half-normal model. In this study, the normal-truncated normal model was adopted as the most important. The log likelihood for the normal-truncated normal model was specified as follow:

$$\log L_i = -\frac{1}{2} \log 2\pi - \log \sigma - \log \Phi(\alpha \sqrt{1 + \lambda^2}) + \log \Phi(\alpha - \varepsilon_i \lambda / \sigma) - \frac{1}{2} (\varepsilon_i / \sigma + \sigma \lambda)^2 \dots \dots \dots (10)$$

Where:

$$\varepsilon_i = y_i - \beta' x_i \lambda$$

$$\lambda = \sigma_u / \sigma_v$$

$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$

$$\sigma = \sqrt{(\sigma_u^2 + \sigma_v^2)}$$

$$\alpha = \mu / (\lambda \sigma)$$

N represents the distribution function of the standard normal random variable.

To determine the relationship between socio-economic characteristics of maize farmers and their levels of production efficiency in the second objective different explanatory variables age; access to credit; access to market; education level household head, access

to extension services , work experience in maize production; gender of respondent, group membership ,family size, and family income were considered.

In this study, a Tobit regression model was used to estimate socio-economic factors affecting the efficiency of smallholder maize farmers in Gatsibo district. The model was chosen because its dependent variable is binary and can only take two values, it allows one to estimate the probability of a certain event occurring.

The Tobit model technical efficiency was presented as follow:

$$Tobit (P) = Ln \left(\frac{P}{1-P} \right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \varepsilon \dots \dots (11)$$

Where

P_i is probability that a farmer is productive

$1-P_i$ is the probability that a farmer is not productive

β_0 is the intercept

$\beta_1-\beta_{10}$ are the regression coefficients;

X_1-X_{10} are the independent variables (explanatory variables) and

ε is the error term. In the linear for the equation become:

$$Ln (PROB) = \beta_0 + \beta_1 AGE + \beta_2 ACRED + \beta_3 DIST + \beta_4 ED + \beta_5 EXT + \beta_6 EXP + \beta_7 GEND + \beta_8 SHIP + \beta_9 HHHS + \beta_{10} FINC + \varepsilon \dots \dots (12)$$

The likelihood ratio can be defined as the ratio of the likelihood of an event occurring in one group to the likelihood of it occurring in another group, or to a sample-based estimate of that ratio Molepo *et al.*, (2011). For this reason, these groups represent

productive and non-productive farmers. The likelihood ratio must be greater than or equal to zero. The likelihood ratio greater than 1 indicates that the event is more likely in the first group, while the likelihood ratio less than 1 indicates that the event is less likely in the first group Molepo *et al.* (2011).

3.6.3 Model specification for economic efficiency

In the form of empirical study, economic efficiency was measured using Cobb-Douglas stochastic frontier cost function for maize production, using the maximum likelihood method.

The determinants of economic efficiency were presented in terms of socio-economic variables and other factors. The econometric model function was specified as follows:

$$EE = (X_{ie}.P)/(X_i.P) \dots \dots \dots (13)$$

Hence, the economic efficiency was simultaneously estimated with their determinants as follow:

$$\text{Exp}(-U_i) = \alpha_0 + \alpha_1 T_1 + \alpha_2 T_2 + \alpha_3 T_3 + \alpha_4 T_4 + \alpha_5 T_5 + \alpha_6 T_6 + \alpha_7 T_7 + \alpha_8 T_8 + \alpha_9 T_9 + \alpha_{10} T_{10} \dots \dots \dots (14)$$

Where:

Exp (-U_i) = economic efficiency of the i-th farmer

α₁ - α₁₀ = parameters to be estimated

T₁- T₁₀= Independent variables

T₁ =Age in years

T₂ =Educational level in years

T₃=Farming experience in years

T₄= Family income in money

T5=Number of extension services

T6= Gender of respondent (1= male variable, 0 otherwise)

T7=Access to credit (1= access, 0 otherwise)

T8=Group membership of farmers cooperatives (1 = member, 0 otherwise)

T9=Household size in numbers

T10=Distance to market in km

By considering, the definition of the independent variables a priori expectation is that educational level, gender, farming experience, extension service, family income, access to credit access and membership of farmers will be positive while age of farmers, distance to market and household size will be negative.

3.7 Definition of Variables

3.7.1 Production function variables

Output: is the dependent variable of the production function. It is the physical quantity of maize produced in kilograms per area of land allocated for each sample household.

Land: Land is the most important input in smallholder production. It is the total area of land used for main crop production in hectare (ha). In this study, it is the amount of land allocated to maize production in area measured in hectare as unit of area.

Labor: is total number of family and hired laborers used in different stages of production such as land preparation, planting, weeding, topdressing, general cultivation activities and harvesting.

Improved seed: This refers to the quantity of improved maize seed used (in kg) for maize production by each household in study area.

Pesticide: is the total expenditure the farmer incurred on pesticide/ fungicide purchase for maize production and it measured in litters.

Fertilizers: is the total amount of both chemical and organic fertilizers used in kilogram. In this study this refers to the amount of DAP, UREA and organic manure used (in kg) by each household for maize production during the production season.

3.7.2 Efficiency variables

Age: This refers to the age of the household head measured in years. It is believed that age can serve as a proxy for experience. Farmers with more years of experience are expected to be more efficient. On the other hand, older farmers are relatively unlikely to change their long life farming exercise. A study made by Amos (2007) indicated that age of farmers was found to have positive effect on technical efficiency of smallholder maize farmers in Nigeria. Empirical studies for example Tan ,*et al.* (2010) argue that older households are more experienced than younger ones.

Household Size: This is a continuous variable representing the total number of family members in the household. Family is an important source of labour supply. In smallholder production, the size of household is a means to have more supply of lab our. Since labour is the main input in crop production, as the farmer has large family size, he/she would manage crop plots on time (Fekadu, 2004). Hence, size of the household is expected to have positive association between production and technical efficiency of the farmer.

Education level: indicates the years of schooling of the household head. Education is usually an indication for quality of lab our. It is argued that skilled farmers to have better skills of managing farm operations and understand new technologies that increase their production. Access to education together with increased experience could guide to better management of farm activities (Tewodros, 2001). Education of the household head was measured in years of formal schooling and hypothesized to affect efficiency positively.

Extension Services: This is a dummy variable taking values of 1 if an extension expert visits the farmer and 0 otherwise. Hence, the impact of extension services on the level of efficiency is expected to be positive. This is because, farmers that have frequent contact with extension expert will have better access to information and new technology that could be productively used on their farm (Fekadu, 2004).

Gender is a dummy variable representing the gender of household head taking a value of 1 for male headed households and 0 for female headed households. Even though women play a substantial role in agricultural activities, there are still tasks that are not done by women for example ploughing. Hence, male-headed households are expected to be more efficient than female-headed households are.

Experience in maize farming: This refers to maize production experience of the household head measured in years. A study by Gul *et al.* (2009) indicated that this variable has positive effect on technical efficiency of sorghum producing farmers in Turkey. As one gets proficient in the methods of production, optimal allocation of resources at his/her disposal should be achieved (Hyuha, 2006). In this case, farmers with more years of experience are expected to be more efficient.

Distance to market: This is the distance of maize production from homestead measured by transporting time required. Thus, market distance was expected to negatively influence the use of required inputs. It is hypothesized that distance of maize production to the market will be negatively related to efficiency.

Access to Credit: This is a dummy variable which represents whether the farmer has obtained credit or not during the production season. If the farmer has taken credit during the given production season, the variable takes a value of 1, and 0 otherwise. It is hypothesized that farmers who have access to credit sources are more efficient than others are. This is because, access to credit is an important source of financing and it enables the smallholder farmers to purchase agricultural inputs on time that would increase their productivity (Ike and Inoni 2006). Even though the effect of credit access

on technical efficiency would depend on the size of the credit, in this study, it was hypothesized that farmers who have access to credit are more technically efficient than non-accessed one.

Family income: is the variable in the focus in this study. This variable forms part of the financial capital owned by a household from all possible income generation sources that they were engaged in including remittances. It was measured as total income earned from various sources in a year of maize production. Income was hypothesized to positively influence on technical efficiency.

Group membership: this is a social capital variable and was measured as a dummy variable the variable takes a value of one in-group member, and zero otherwise. For purposes of this study, the group membership was a variable that took into consideration those groups that have a component of maize production in area. Hence, it was expected that this variable would have a positive effect on efficiency.

CHAPTER FOUR:

RESULTS AND DISCUSSION

4.1 Descriptive analysis results

4.1.1 Demographic and socio-economic characteristics of sampled households

The study identified the characteristic of the respondents. The findings such as frequency, percentage and mean are presented in the different tables and graphs below.

Table 1 shows the gender distribution of respondents in the study area.

Table 4. 1: Socio-economic characteristics of respondents

Descriptive characteristics	Frequency	Percentage
Gender of respondents		
Male	96	57.14
Female	72	42.86
Ages of respondents		
20-25	8	4.8
26-35	34	20.2
36-45	62	36.9
46-55	48	28.6
Above 55	16	9.5
Family size of respondents	Frequency	Percent
1-2	14	8.3
3-4	18	10.7
5-6	94	56
6-8	28	16.7
Above 8	10	6
Education level of respondents		
Illiterate	14	8.3
Primary	74	44
Secondary	32	19
Vocational	24	14.3
University	18	10.7
Experience of respondents		
3 and less	14	8.3
4-5	68	40.6
Above 6	84	50.1

The study indicated that male (57.14 %) and (42.86%) female farmers participated in maize production indicating that the crop is important for both gender groups. Results in table 4.1 indicated that there were farmers below 25 years and above 50 years indicating that while some areas had stronger farmers, others had less active ones involved in maize production (table 4.1).

Results indicated that majority (57%) of the respondents have a family size ranging from 5 to 6 members implying that a large family size would and hence increase the profitability of maize production. This was supported by the study like seidu (2018) which emphases to those large households in improving farm efficiency.

The results indicated that a few number of farmers in study area they have primary while a good number have secondary (19%) vocational (14.3%) and university (10.7%) education. This high percentage of educated farmers should have positive impact on maize productivity through quick understanding of trainings given on the crops management like cultural best practices, pests and diseases control and the adoption of new techniques of production. This study concur with Nyakaga *et al.*, (2009) who found that the farmer's education of Kenya positively influenced farm economic efficiency.

Results demonstrated that majority (50.1%) of the respondents were experienced in producing maize crops for over six years for commercial purpose implying a positive impact on maize output followed by 40.6%) of respondents producing maize crops between 4 and 5 years. This is supposed to have positive impact on maize output through adoption of new use of inputs like improved maize varieties and fertilizers. Farming experience has also been found to influence farm output. Various authors have found that experience in farming enhances efficiency Mulwa *et al.*, (2009) in western Kenya observed that farming experience had a positive influence on economic efficiency. Mbanasor & Kalu (2008) also found similar results for vegetable farmers in Nigeria, which coincides with their findings for age. It is expected that experienced farmers have over the years learned from their mistakes and improved their efficiency in

production. The farmers with high experience are also easy to be trained on cultural best practices and diseases control through farmer's field school.

4.1.2 Variables used to estimate production function

The summary statistics for the variables used in the study were presented in Table 4.2. The production function for this study was estimated using six inputs variables and ten variables for estimating efficiency. The result showed that the minimum yield of maize obtained is 150 kg/ha and the maximum is 4800 kg/ha. The average values for seeds and chemical fertilizer inputs ranges between 10-21.4 and 20-67 kg per hectare, respectively. The average value for organic manure used was 7440 kg/ha, it ranges between a minimum of 1500kg/ha to a maximum of 10000kg/ha. The average value for pesticide used was 1.54 litter /ha, it ranges between a minimum of 0.2 /ha to a maximum three litters /ha. The average figure for labor is 178 person-days per hectare with a range of 45 man-days/ha to 370 person-days per hectare. The average years of education are 7.6 years, with a minimum of zero and maximum of 16 years. The average figure for years' experience is 9.2 the value range between 3 to 23 years in maize farming. The average distance to input market was 19.3 km, it ranges between a minimum of 0.5 km to a maximum of 50 km. The average the size of the household was 3.8 persons with a minimum range of one person and maximum of eight persons. The average years for household head were 43 years old with a minimum range of 20 years to a maximum of 70 years. The average land area allocated to maize production for household was 2.14 ha with a minimum range of 0.2hectare to a maximum of 4 hectare.

Table 4. 2 Descriptive statistics for the model variables

Variables	Description	N	Units	Mean	Std. Deviation	Min	Max
land	Land area under maize	168	Ha	2.14	1.532319	0.2	4
Yield	Total output of maize produced	168	Kg	2330	2026.882	150	4800
labor	Labor used in maize production	168	Man-days	178	133.351	45	370
Organic fertilizer	Amount of organic fertilizer	168	Kg	7440	3452.246	1500	10000
Chemical Fertilizer	Amount of chemical fertilizer	168	kg	67	50.92151	20	150
Pesticide	Amount of pesticide applied	168	L	1.54	1.217785	0.2	3
Seeds	Amount of seed planted/sowed	168	Kg	21.4	7.668116	10	30
Income	Income used in maize production	168	rwf	106600	95747.06	15000	250000
Distance	Distance to market in Km	168	Km	19.3	20.39485	0.5	50
Credit	Access to agricultural credit	168	1=yes ,0= otherwise	0.8	0.4472136	0	1
Education	Education level of respondent	168	Years	7.6	6.387488	0	16
Experience	Farming experience in years	168	Years	9.2	8.01249	3	23
HH size	Number of individuals in the HH	168	Number	3.8	2.774887	1	8
Extension	Extension service for farmers	168	1=yes,0= otherwise	0.8	0.4472136	0	1
Age	Age of household head	168	Years	43	19.87461	20	70
Membership	Membership of head HH in group	168	1=yes,0= otherwise	0.8	0.4472136	0	1
Sex	Sex of household head	168	1=male,0=otherwise	0.8	0.4472136	0	1

4.2 Empirical analysis results

4.2.1 Factors of maize productivity

To identify the factors influencing maize productivity, a stochastic frontier production function was estimated and the results are presented in Table 4.3. Five variables (Land size, labor, improved Seeds, chemical fertiliser, & organic fertilize) were found to significantly affect bean productivity. The model results further show that the variance of the technical inefficiency parameter γ is 0.765 and is significantly different from zero. This value is of 0.765 showed that 76.5% of the difference between the observed and the actual output were due to technical inefficiency of farms.

The following elasticities were generated from the stochastic production frontier estimation: improved seeds (0.215), land size (0.392), organic manure (0.045), labour (0.307), pesticides (-0.009), chemical fertilizer (0.140). The result further indicated that the return to scale parameter obtained by summing up the coefficients for the inputs is 1.09. This indicates that maize production in study area exhibits constant returns to scale, implying that farmers in the study area use traditional maize production techniques which have become redundant over time; although if they embraced the technological improvements they can improve their productivity. Land size had the

largest elasticity, followed by labor and then improved seeds while pesticides had the smallest elasticity. The five inputs showed a positive impact on productivity and were statistically significant at 1% and 5% level; this underscores the importance of all the inputs to maize productivity Gatsibo district.

Land size, and improved seeds had a strongly significant effect on maize productivity at 1% level. The results showed that a 1% increase in the land size used significantly increased maize yields by 39.2%. While a 1% increase in the improved seeds used significantly increased maize yields by 21.5.2%. This suggests that planting more seeds improved maize productivity significantly. This implies that any interventions to increase productivity of seed and land size would create significant achievements in maize productivity in Gatsibo.

The importance of seeds in determining productivity has also been emphasised by Reardon *et al.* (1997), although it is important to note that for seed to make its full contribution to bean productivity in Sub-Saharan Africa, the farmers need to use certified seeds, which have an assurance of quality. However, the seed variety used is also important in determining the contribution of seeds to maize productivity. Better and improved seed varieties may be able to produce high yields even without planting many seeds per hole.

Table 4. 3: Stochastic frontier production function results

Explanatory variables	Coefficient	Standard Errors	z	P> z
Land size(Ha)	0.392	0.207	0.568	0.000***
Improved seeds (Kg/ha)	0.215	0.063	3.412	0.003***
Labour used (man-day/ha)	0.307	0.031	9.903	0.054**
Chemical fertilizers (kg/ha)	0.140	0.047	0.297	0.067*
Organic manure (kg/ha)	0.045	0.027	0.977	0.021**
Pesticides (Litres/ha)	-0.009	0.350	0.524	0.663
Constant	3.567	0.642	5.566	0.000***
(σ_v)	0.647	0.039		
(σ_u)	1.163	0.145		
(σ^2)	1.768	0.371		
(γ)	0.765			

The findings also showed a positive coefficient for land size as was postulated. Land size has a strongly significant influence on maize productivity at 1% level. According to the results, an increase in the land size by 1% significantly increased the farmer's maize productivity by 39.2%. This suggests that the more farm land a farmer allocated to maize farming, the higher the yields obtained per unit area.

Improved seed also showed a positive effect on maize productivity according to the findings. It was indicated that improved seed had a significant influence on bean yields at 1% level, since a 1% increase in the quantity of improved seed used increased maize productivity by 21.5%. This suggests that the more improved seeds a farmer was able to plant on the farm, the higher were the maize outputs.

It was also found that planting fertilizer both organic manure and chemical fertiliser showed a positive coefficient as hypothesised, with a significant relationship with maize yields at 5% & 10% level respectively. The results revealed that a 1% increase in the quantity of organic manure applied, significantly improved maize productivity by 4.5%. While a 1% increase in the quantity of chemical fertilizers applied, significantly improved maize productivity by 414 %. This suggests that increasing the amount of

fertilizer (organic and chemical) used would contribute to higher maize yields in the area. The results are consistent as hypothesised and they reflect the findings presented by Tchale (2009) in Malawi where fertilizer was a key factor in production of major crops grown by smallholder farmers.

It was also found that labour showed a positive coefficient as hypothesised, with a significant relationship with maize yields at 5%. The results revealed that a 1% increase in the quantity of labour used in maize production, significantly improved maize productivity by 30.4%.

4.2.2 Predicted allocative, technical and economic efficiency scores

The efficiency scores for technical, economic and allocative efficiency among sampled maize farms in Gatsibo were summarized in Table 4.4. The scores for technical and economic efficiency were predicted after estimating the stochastic frontier production and cost functions respectively; whereas the allocative efficiency scores were computed as the quotient between EE and TE. The mean technical, allocative, and economic efficiency score for the sampled farms were 51.78%, 63.17%, & 54.17 % respectively. The minimum technical, allocative, and economic efficiency score for the sampled farms were 0.757 %, 0.38%; & 5.33 % respectively. The maximum allocative, technical and economic efficiency score for the sampled farms were 76.44%; 87.55%, & 91.41% respectively.

Table 4. 4: Predicted locative, technical and economic efficiency scores

Efficiency Range (100%)	AE		TE		EE	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
0-24	62	36,91	63	37,5	5	2.98
25-49	76	45,24	6	3.57	23	13.69
50-74	29	17,26	87	51.79	91	54.17
75-100	1	0.59	12	7.14	49	29.16
Total	168	100	168	100	168	100
Minimum		0.38		0.575		5.33
Maximum		76.44		87.55		91.41
Mean		63.17		51.78		54.17
Std.dev		20.1		23.465		22.22

4.2.3 Determinants of technical efficiency

The results in Table 4.5 indicated that the estimates from a tobit regression of socio-economic and institutional factors against predicted technical efficiency scores. The results of model indicated that the chi-square was 43.35 and it was statistically significant at 1% level. The pseudo R2 was 63.7% against the recommended level of 20%. This is the important evident indicating that the explanatory variables for the model were able to explain 63.7% of the variations in technical efficiency levels. According to results found all ten variables were found to have a significant contribution on technical efficiency. Factors ;such as access to credit; extension services, work experience in maize production; and family income were found to be statistically significant at 1% level on the influence of the technical efficiency in the study area. The variables namely education level of household head, group membership, and gender of respondent were found to be statistically significant at 5% level on the influence of the technical efficiency. The tree variables family size, distance to market, and age were found to be statistically significant at 10% level on the influence of the technical efficiency.

Table 4. 5: Tobit regression estimates of factors influencing technical efficiency

Technical Efficiency	Coefficient	Standard Errors	z	P> z
Constant	1.406	2.135	0.066	0.000***
Age (years)	-0.042	-0.004	10.50	0.072*
Educational (years)	0.053	0.010	5.300	0.013**
Farming experience (years)	0.067	0.095	0.705	0.001***
Family income in money(rwf)	0.081	0.037	2.189	0.000***
Extension services	0.034	0.049	0.693	0.003***
Gender of respondent	0.011	0.023	0.478	0.056**
Access to credit	0.045	0.099	0.454	0.000T***
Group membership	0.066	0.037	1.783	0.029**
Household size in (numbers)	0.127	0.204	0.623	0.067*
Distance to market(km)	-0.059	0.501	-1.118	0.081*
Log likelihood = 53.72		LR chi2 (10) = 46. 35		
Pseudo R2 = -0.637		Prob> chi2 = 0.000		

***, **, *** is significant at 10%, 5% and 1% respectively**

The access to credit indicated a positive influence on technical efficiency as hypothesized and was significant at 1% level. The results indicated that a unit increase in the access to credit owned by a household increased technical efficiency by 4.5%.

Extension services also displayed a positive and strong significant influence on technical efficiency at 1% level. According to the findings, maize farmers who accessed extension services pointed out a higher level of technical efficiency by 3.4%, than those who failed to access the services.

This revealed that access to extension services help maize farmers to obtain information on different good agricultural practices such as land preparation, planting,

weeding, fertilizers application pests and diseases control methods and insights on innovative farming techniques that guarantee higher productivity of maize crop. The results were supported by Seidu(2008) observed that farmers who get adequate extension contacts are able to access modern agricultural technology for input mobilization, input use and disease control, which enable them to reduce technical inefficiency.

Farming experience also displayed a positive and strong significant influence on technical efficiency at 1% level. According to the findings, maize farmers who had an experience in maize farming showed out a higher level of technical efficiency by 6.7%

Family income also displayed a positive and strong significant influence on technical efficiency at 1% level. According to the findings, maize farmers who had a family income indicated a higher level of technical efficiency by 8.1%. This implies that a 1% increase in the family income owned by a household increased technical efficiency by 8.1%.

Technical efficiency was also influenced by a maize farmer participated in producer cooperative/group. Due to the findings, group membership indicated a positive and significant relationship at 5% level; it implies that the farmers who were members in a producer cooperative/group improved their technical efficiency levels by 6.6%.

Idiong (2007) in his study on the smallholder swamp rice among producers in Nigeria observed that farmers who are members in producer organizations are able to benefit not only from the shared knowledge among themselves with respect to modern farming methods, but also from economies of scale in accessing input markets as a group. Hence, such farmers become more technically efficient in production.

Gender of the household head has a positive and significant influence at 5% level on technical efficiency. It was indicated that 1 % increase in male-headed households the technical efficiency will be increased by 1.1%. it is also implies that male-headed

households are more technically efficient than female headed households. The result was also supported by Msuya ,*Hisano and Nairu*(2008) found the same correlation between gender of the household head and technical efficiency.

In this study, the household head age showed a negative effect on technical efficiency of the maize farms as was hypothesized and it was significant at 10% level. The results revealed that 1% increase in the farmer's age by one year reduced the level of technical efficiency by 4.2%.

The distance to market indicated a negative effect on technical efficiency of the maize farms and it was significant at 10% level. The results revealed that 1% increase in the distance to market by one kilometer reduced the level of technical efficiency by 5.9 %. The findings are consistent with results found by Bagamba F.Ru, *al.* (2007) among smallholder banana producers in Uganda. They observed that households located nearer to the factor markets showed higher technical efficiency than those located in remote areas.

4.2.4 Determinants of economic efficiency

The results in Table 4.6 indicated that the estimates from a tobit regression of socio-economic and institutional factors against predicted economic efficiency scores. The results of model indicated that the chi-square was 42.61 and it was statistically significant at 1% level. The pseudo R² was 69.7% against the recommended level of 20%. This was the important evident indicating that the explanatory variables for the model were able to explain 69.7% of the variations in economic efficiency levels. According to results found eight in ten variables were found to have a significant contribution on technical efficiency. Factors such as access to credit, and family income were found to be statistically significant at 1% level on the influence of the economic efficiency in the study area.

The results of this study in table 4.6 indicated that the household head age showed a negative effect on economic efficiency of the maize farms as was hypothesized and it

was significant at 5% level. The results revealed that 1% increase in the farmer's age by one year reduced the level of economic efficiency by 0.7%.

The distance to market indicated a negative effect on economic efficiency of the maize farms and it was significant at 10% level. The results revealed that 1% increase in the distance to market by one kilometer reduced the level of economic efficiency by 2 %.

Table 4. 6: Tobit regression estimates of factors influencing economic efficiency

Technical Efficiency	Coefficient	Standard Errors	z	P> z
Constant	3.221	2.09	1.541	0.002***
Age (years)	-0.007	0.81	-0.001	0.037**
Educational (years)	0.053	0.401	0.132	0.061*
Farming experience (years)	0.002	0.06	0.033	0.037**
Family income in money(rwf)	0.041	0.87	0.047	0.005***
Extension services	0.150	1.430	1.442	0.014**
Gender of respondent	-0.124	0.012	-1.033	0.454
Access to credit	0.008	0.011	0.727	0.004***
Group membership	0.079	0.057	1.389	0.482
Household size in (numbers)	0.075	0.048	1.563	0.083*
Distance to market(km)	-0.020	0.307	-0.83	0.076*
Log likelihood = 51.453			LR chi2(10) = 42.641	
Pseudo R2 = -0.697			Prob> chi2 = 0.000	

***, **, *** is significant at 10%, 5% and 1% respectively**

The access to credit indicated a positive influence on economic efficiency as hypothesized and was significant at 1% level. The results indicated that a unit increase in the access to credit owned by a household increased economic efficiency by 0.8 %. Gonaives *et al.* (2008) reported the findings in his study among milk producing farms in Brazil. In this study, it was found that access to credit is important in production in the sense that it improves farmers' ability to purchase the otherwise unaffordable farm inputs and consequently it significantly improves their level of efficiency.

Family income also displayed a positive and strong significant influence on economic efficiency at 1% level. According to the findings, maize farmers who had family income pointed out a higher level of economic efficiency by 4.1%. It implies that a unit increase in the family income owned by a household increased economic efficiency by 4.1 %.

Extension services also displayed a positive and significant influence on economic efficiency at 5% level. According to the findings, maize farmers who accessed extension services pointed out a higher level of technical efficiency by 15 %, than those who failed to access the services.

Farming experience also displayed a positive and significant influence on economic efficiency at 5 % level. According to the findings, maize farmers who had an experience in maize farming showed out a higher level of economic efficiency by 0.2%

Technical efficiency was also influenced by a maize farmer participated in producer cooperative/group. According to the findings, group membership indicated a positive and significant relationship at 5% level; it implies that the farmers who were members in a producer cooperative/group improved their technical efficiency levels by 7.9%.

In this study, the household head age showed a negative effect on economic efficiency of the maize farms as was hypothesized and it was significant at 5% level. The results revealed that 1% increase in the farmer's age by one year reduced the level of economic efficiency by 0.7%. The distance to market indicated a negative effect on technical efficiency of the maize farms and it was significant at 10% level. The results revealed that 1% increase in the distance to market by one kilometer reduced the level of technical efficiency by 2 %.

4.2.4 Determinants of allocative efficiency

The results in Table 4.7 indicated that the estimates from a tobit regression of socio-economic and institutional factors against predicted allocative efficiency scores. The results of model indicated that the chi-square was 67.58 and it was statistically

significant at 1% level. The pseudo R2 was 32.7% against the recommended level of 20%. This was the best a turn signal indicating that the explanatory variables for the model were able to explain 32.7% of the variations in economic efficiency levels. According to results found seven in ten variables were found to have a significant contribution on allocative efficiency. Factors education level of a household head was found to be positive and strongly significant at 1% level on the influence of the allocative efficiency in the study area.

The results of this study in table 4.6 indicated that the household head age showed a negative effect on allocative efficiency of the maize farms as was hypothesized and it was significant at 5% level. The results revealed that 1% increase in the farmer's age by one year reduced the level of allocative efficiency by 4.5%. The distance to market indicated a negative effect on allocative efficiency of the maize farms and it was significant at 10% level. The results revealed that 1% increase in the distance to market by one kilometer reduced the level of allocative efficiency by 6.6%.

Table 4. 7: Tobit regression estimates of factors influencing allocative efficiency

Allocative Efficiency	Coefficient	Standard Errors	z	P> z
Constant	0.529	0.913	0.579	0.000***
Age (years)	-0.451	0.211	-2.137	0.029**
Education level (years)	0.026	0.017	0.153	0.000***
Farming experience (years)	0.545	0.257	2.121	0.054**
Family income in money(rwf)	0.005	0.006	0.833	0.041**
Extension services	0.019	0.031	0.613	0.912
Gender of respondent	-0.062	0.030	-2.067	0.520
Access to credit	0.073	0.069	1.058	0.097*
Group membership	0.08	0.026	3.076	0.068*
Household size in (numbers)	0.051	0.002	2.55	0.014**
Distance to market(km)	-0.066	0.056	-1.178	0.074*
Log likelihood = -110.36			LR chi2(12) = 67.58	
Pseudo R2 = 0.327			Prob> chi2 = 0.000	

***, **, *** is significant at 10%, 5% and 1% respectively**

The results in table 4.7 showed that distance to the input market had a negative influence on allocative efficiency as previously expected and it was significant at 10% level. It was found that an increase in the distance to the market by one kilometer; the allocative efficiency will be reduced by 6.6%. Therefore the households located nearer the markets showed higher allocative efficiency than those located far from the areas. This is because a farm located far from the market incurs more costs to transport farm inputs from the market all the way to the farm. As such, nearness to the market improved allocative efficiency among bean producers in the study area. The results were supported by the study of Bagamba *et al.* (2007) among smallholder banana producers in Uganda. The authors attributed their findings to the fact that the nearness to the factor markets increased farmers' access to credit facilities and non-farm income generating activities that enable farmers to afford and apply inputs on time.

CHAPTER FIVE:

CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The main objective of this study was to conduct an economics analysis of the factors influencing maize productivity and efficiency among farmers in Gatsibo district, Rwanda. The study was conducted in Gatsibo districts. A sample size of 168 households selected using a multi-stage sampling technique. For the data collection, a personally administered structured questionnaire was used to conduct interviews, with a focus on household heads. A stochastic frontier model was also used to estimate efficiency allocative, economic and technical efficiency and determinants of maize productivity. The Cobb-Douglas stochastic frontier production model was used to estimate the production functions. A Tobit model was chosen to evaluate the factors influencing allocative, technical, and economic efficiency levels. The descriptive statistics for the variables used in the study were presented in Table 4.2. The production function for this study was estimated using six inputs variables and ten variables for estimating efficiency. The result showed that the minimum yield of maize obtained is 150 kg/ha and the maximum is 4800 kg/ha. The average values for seeds and chemical fertilizer inputs ranges between 10-21.4 and 20-67 kg per hectare, respectively. The average value for organic manure used was 7440 kg/ha, it ranges between a minimum of 1500kg/ha to a maximum of 10000kg/ha. The average value for pesticide used was 1.54 litter /ha, it ranges between a minimum of 0.2 /ha to a maximum three litters /ha. The average figure for labor is 178 person-days per hectare with a range of 45 man-days/ha to 370 person-days per hectare. The average years of education are 7.6 years, with a minimum of zero and maximum of 16 years. The average figure for years' experience is 9.2 the value range between 3 to 23 years in maize farming. The average distance to input market was 19.3 km, it ranges between a minimum of 0.5 km to a maximum of 50 km. The average the size of the household was 3.8 persons with a minimum range of one person and maximum of eight persons. The average years for household head were 43 years old

with a minimum range of 20 years to a maximum of 70 years. The average land area allocated to maize production for household was 2.14 ha with a minimum range of 0.2hectare to a maximum of 4 hectare.

This study used a stochastic frontier analysis to estimate and analyst efficiencies of smallholder maize farmers in Gatsibo district. With Tobit regression model the factors influencing allocative, technical, and economic efficiency gave the following results.

The following elasticities were generated from the stochastic production frontier estimation: improved seeds (0.215) land size (0.392) organic manure (0.045) lab our (0.307) pesticides (-0.009) chemical fertilizer (0.140). The result further indicated that the return to scale parameter obtained by summing up the coefficients for the inputs is 1.09. This indicates that maize production in study area exhibits constant returns to scale, implying that farmers in the study area use traditional maize production techniques which have become redundant over time; although if they embraced the technological improvements they can improve their productivity. Land size had the largest elasticity, followed by labor and then improved seeds while pesticides had the smallest elasticity. The five inputs showed a positive impact on productivity and were statistically significant at 1% and 5% level; this underscores the importance of all the inputs to maize productivity Gatsibo district.

The efficiency scores for technical, economic and allocative efficiency among sampled maize farms in Gatsibo were summarized in Table 4.4 The scores for technical and economic efficiency were predicted after estimating the stochastic frontier production and cost functions respectively; whereas the allocative efficiency scores were computed as the quotient between EE and TE. The mean technical, allocative, and economic efficiency score for the sampled farms were 51.78%, 63.17%, and 54.17 % respectively. The minimum technical, allocative, and economic efficiency score for the sampled farms were 0.757 %, 0.38%; and 5.33 % respectively. The maximum allocative, technical and

economic efficiency score for the sampled farms were 76.44%; 87.55%, and 91.41% respectively.

The results in Table 4.5 indicated that the estimates from a tobit regression of socio-economic and institutional factors against predicted technical efficiency scores. The results of model indicated that the chi-square was 43.35 and it was statistically significant at 1% level. The pseudo R2 was 63.7% against the recommended level of 20%. This is the important evident indicating that the explanatory variables for the model were able to explain 63.7% of the variations in technical efficiency levels. According to results found all ten variables were found to have a significant contribution on technical efficiency.

The results in Table 4.6 indicated that the estimates from a tobit regression of socio-economic and institutional factors against predicted economic efficiency scores. The results of model indicated that the chi-square was 42.61 and it was statistically significant at 1% level. The pseudo R2 was 69.7% against the recommended level of 20%. This was the important evident indicating that the explanatory variables for the model were able to explain 69.7% of the variations in economic efficiency levels. According to results found eight in ten variables were found to have a significant contribution on technical efficiency. Factors such as access to credit, and family income were found to be statistically significant at 1% level on the influence of the economic efficiency in the study area.

The results in Table 4.7 indicated that the estimates from a Tobit regression of socio-economic and institutional factors against predicted allocative efficiency scores. The results of model indicated that the chi-square was 67.58 and it was statistically significant at 1% level. The pseudo R2 was 32.7% against the recommended level of 20%. This was the best a turn signal indicating that the explanatory variables for the model were able to explain 32.7% of the variations in economic efficiency levels. According to results found seven in ten variables were found to have a significant

contribution on allocative efficiency. Factors education level of a household head was found to be positive and strongly significant at 1% level on the influence of the allocative efficiency in the study area.

5.2 Conclusion

The main objective of this study was to conduct an economics analysis of the factors influencing maize productivity and efficiency among farmers in Gatsibo district, Rwanda. It was found that maize productivity was significantly influenced by improved seeds, land size, organic manure, lab our and chemical fertilizer. The following elasticities were generated from the stochastic production frontier estimation: improved seeds (0.215) land size (0.392) organic manure (0.045) lab our (0.307) pesticides (-0.009) chemical fertilizer (0.140). The result further indicated that the return to scale parameter obtained by summing up the coefficients for the inputs is 1.09. This indicates that maize production in study area exhibits constant returns to scale, implying that farmers in the study area use traditional maize production techniques which have become redundant over time; although if they embraced the technological improvements they can improve their productivity. Land size had the largest elasticity, followed by labor and then improved seeds while pesticides had the smallest elasticity.

It was found that the five inputs such as land size, improved seeds, organic manure, labour, and chemical fertilizer revealed a positive influence on maize productivity and were statistically significant at 1% and 5% level. Hence, underscores the importance of all five inputs to maize productivity in Gatsibo district. Productivity of maize should be increased through the improvement of the state of technology, enhancing the efficiency of producers and resource reallocation. This study analyzed the technical, allocative and economic efficiencies and factors that explain the variation in efficiency among maize farmers in Gatsibo district. The study result indicated that the mean technical, allocative, and economic efficiency score for the sampled farms were 51.78%, 63.17%, and 54.17 % respectively. This implies that farmers can increase their maize productivity on the average by 48.22% if they were technically efficient. Likewise, maize farmers should

increase their maize productivity on the average by 36.862% if they were allocative efficient, in the same manner maize farmers should increase their maize productivity on the average by 45.832% if they were economic efficient.

Factors such as access to credit; extension services, work experience in maize production; and family income were found to be statistically significant at 1% level on the influence of the technical efficiency in the study area. While the household head age and distance to market showed a negative effect on technical efficiency of the maize farms as were hypothesized and they were significant at 10% level. Factors such as access to credit, and family income were found to be statistically significant at 1% level on the influence of the economic efficiency in the study area while household head age and distance to market indicated a negative effect on economic efficiency of the maize farms and it was significant at 5% and 10% level respectively. Finally, education level of respondents was found to be statistically significant at 1% level on the influence of the allocative efficiency in the study area hence two factors namely household head age and distance to market indicated a negative effect on allocative efficiency of the maize farms.

5.3 Recommendations

This study used a stochastic frontier analysis to estimate and analyze the productivity and efficiencies among maize farmers. Based on the findings of this study, the following recommendations were found out:

1. The result further indicated that the return to scale parameter obtained by summing up the coefficients for the inputs is 1.09. This indicates that maize production in study area exhibits constant returns to scale, implying that farmers in the study area use traditional maize production techniques that have become redundant over time. A high level of financial support should be help to acquire necessary inputs for maize production and expanding extension services for easy adoption of technology and implementation of inputs use. This kind of policy

may be very important in achieving increased efficiency and maize productivity of farmers.

2. Farming experience and extension services indicated a positive and significant influence on both technical and allocative efficiency. Different strategies and policies should be more emphasised on through strengthening the existing agricultural extension service provision through providing incentives, FFS, training, workshops, and providing upgrading educational level to both farmer producers and extension experts.
3. Factors such as access to credit and family income were found to be statistically significant at 1% level on the influence of the technical and economic efficiency in the study area. Efforts should be made to the banks and private sectors to make agricultural credit accessible as well as to increase maize productivity;
4. In this study, the household head age and distance to market showed a negative effect on technical, allocative and economic efficiency of the maize farms. The youth should be mobilized and encouraged to enter agricultural sector and government should reduce the distance for market inputs by providing new markets near the big farmers;
5. A group membership indicated a positive and significant influence on both technical and allocative efficiency. It implies that the farmers who were members in a producer cooperative/group improved their technical and allocative efficiency level. For the reason smallholder farmers should be encouraged to form effective producer groups, associations/cooperatives and networks, which will help, improve their bargaining power when purchasing inputs, accessing extension services as well as borrowing farming loans and marketing their produce.

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APPENDICES

APPENDIX 1. INTRODUCTORY LETTER

Dear Sir/Madam,

I am Gaspard Ntabakirabose a Student in Master of Science in Agriculture and Applied Economic in JKUAT. I am carrying out an academic research on the Topic of “**An economic analysis of the factors influencing maize productivity and efficiency in Rwanda: a case study of Gatsibo district.**” The aim of this research is to fulfill partially the academic requirements for the award of the degree of Msc. In Agriculture and Applied Economic in JKUAT.

I kindly request you to answer the following questions as honestly as possible. All the information provided will be treated with highest degree of confidentiality and its use will be only for the purpose of this study.

I look forward to hearing from you.

Yours faithfully

NTABAKIRABOSE Gaspard

Tel: 0788513922

APPENDIX 2: QUESTIONNAIRE

SECTION A: FARMERS' HOUSEHOLD CHARACTERISTICS

Sex of household head	Age in years	Education level	Marital status	Family size	Farming experience Number of years
1= Male 0= Female	Actual number of years	Number of years spent in school	1=Single 2= Married 3=Divorced 4=Separated 5=Widowed	How many people are currently living with you?	How many years have you been Farming maize crop?

SECTION B: STRUCTURE OF LAND OWNERSHIP AND USE

Total size		Tenure system (in ha)			
		Owned	Rented in	Rented out	Communal
Ha					

SECTION C: AGRICULTURAL TECHNOLOGIES USED

Agricultural Practice/technology	(a) Do you know this Technology? 1=Yes 0=No	(b)Source of Technology? (see codes)	(c) Did you seek Information on Technology? 1=Yes 2=No	(d) Have you ever used this technology in your bean fields 1=Yes 0=No	(e)Year you first used this technology	(g) If you did not use this technology during the 2010/11 Season why?
land preparation						
Planting						
Mulching						
Weeding						
Top dressing						
Weeding						

Spraying						
Pests and diseases control						
Irrigation						
Crop rotation						
Harvesting						
Other1, specify						
Which maize varieties did you cultivate last season						
Improved seed						
Non improved						

Codes for source of information on technologies:

1=Government Extension experts

2=Farmer Group members,

3=NGO (specify),

5=other farmers,

Common source of inputs:

1=Purchased from market;

2=Purchased from stockists;

3=Purchased from other farmers

4=Received from government;

5=Received from NGOs;

6=Others (specify)...

Main challenge to access:

1=Too far from household;

2=Unsuitable packaging (large);

3=No knowledge of how to use;

4=No transport;

5= Others (specify)

SECTION F: AVERAGE ANNUAL HOUSEHOLD INCOME SOURCES

Type of earning or income Amount Frequency	Current Income 2015		Was income more same or Less compared to previous years?1=less, 2=same, 3=more
	Amount	Frequency	
Income from different business			
Employment income			
Income from farm produce sales (maize produce)			
Income from sale of livestock and movable asset value			
Transfer earnings from relatives			
Borrowing			
Loans from credit			
Other income(specify)			

SECTION G: MAIZE PRODUCTION ISSUES

1). Did you have land that you did not use in the last growing season? 1=Yes; 0=No.

What of 2015? 1=Yes, 0= No

2). If yes, what was the size of the unused land: 2014?2013.....

3). Gender and labour distribution households

Ploughin g	Plantin g	Weedin g	Fertilizin g	Sprayin g	Harvestin g	Post harvest handlin g	Marketin g produce

Codes:

1=Husband only;

2=Wife only;

3=Husband mostly;

4=Wife mostly;

5=Husband and wife equally;

6=Children;

7=Hired labour;

8=Other (specify)...

4). Have you experienced any maize yield reduction in the last 1-2 years?

1=Yes; 2=No

If Yes, give reasons.

5). Have you experienced any maize yield reduction in the last 4-5 years ago?

1=Yes; 2=No

If yes, give reasons.

6) Do you know any factors/ practices that cause soil depletion?

1=Yes; 0=No

If yes, list them.

7). What factors affected your maize yields? Rank them in terms of significance

(1)

(2)

(3)

SECTION H: ACCESS TO MARKET

		Distance in Km		Means of travel		Time in minutes	
		Current period	Before 2014	Current period	Before 2014	Currently 2015	Before 2013
Input market	Nearest market						
	Most urban market						
Output market	Nearest market						
	Most urban market						
Distance and time to Main Road							

Purpose:

1= Food only;

2= Sell in case of emergency;

3=Food but sell when has plenty;

4=For both food and sale;

5=for sale only;

6=others (specify)...

Marketed:

1=Self/individually;

2=collectively through network/group;

3=Both self and group;

Keeps the money:

1=Husband;

2=Wife;

3=Boy child;

4=Girl child;

6=Others (specify)

2) Have you ever organized yourself with other farmers to sell maize s in-groups?

(In 2014) 1=Yes 0=No, _____

b) When did you join the collective activity _____

3) If yes, with whom, how many times, what markets/where and what was the difference in selling as a group?

With whom	Proportion collectively sold	How many times	What Markets?	What was the difference in price received? 0=lower 1=same 2=better	Distance to market/selling point	Means of transport

Codes for place of sale:

1=on farm;

2=Roadside near village;

3=Local market;

4=District town;

5=Distant market;

6=Others (specify)...

Codes for transport means:

1=Private car;

2=Public vehicle;

3=Motorbike;

4=Bicycle;

5=Walking;

6=Other, specify

4) Are you currently a member of any farmers' group or local association in this Village?

If yes, give the name.

5) Have you ever borrowed money from any of the following sources in the last year or Over the last three years? If yes, how much

6) Would you like to make any comments/suggestions or ask questions?

1=Yes 0=No,

If yes, what are the comments/suggestions or questions?

THANK YOU SO MUCH.