

**COMPARATIVE ANALYSIS OF TECHNICAL EFFICIENCY AND PRODUCTIVITY
DIFFERENCES IN MAIZE FARMING IN GHANA**

BY

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN
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DECLARATION

I, BENJAMIN GIDI CLINTON, author of this thesis titled “**COMPARATIVE ANALYSIS OF TECHNICAL EFFICIENCY AND PRODUCTIVITY DIFFERENCES IN MAIZE FARMING IN GHANA**” do hereby declare that except for the references cited, which are duly acknowledged, this thesis is the product of my own research work in the Department of Agricultural Economics and Agribusiness, University of Ghana, from August 2017- July 2018. This thesis is not published or submitted either in part or in whole anywhere for the award of any degree.

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DEDICATION

This thesis is first dedicated to the Almighty God. It is also dedicated to my beloved parents Mr Wise Gidi Clinton and Mrs. Esther Gidi Clinton and my entire family.

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ABSTRACT

This study aims to determine the differences in productivity and technical efficiency levels of maize producers in three ecological zones in Ghana. It also seeks to identify the sources of inefficiency and identify constraints faced by maize farmers within these ecological zones. The study used a cross section of 224 maize producers from the savannah, forest and transition zones in Ghana. This research adopts the Metafrontier and the stochastic frontier models to compute the technical efficiencies, environmental-technology gaps and relative technical efficiencies of maize farmers from the three zones. The Ox programme was used to analyze the data from the field survey. The translog model proved to be the best fit for the mean output function. All inputs positively influenced the productivity of maize producers in all three ecological zones while intermediate input had an adverse effect on productivity in the savannah zone. The mean technical efficiency scores of the savannah, transition, forest zones and pooled model were found to be 0.78, 0.97, 0.97 and 0.95 respectively. The mean ecological gap ratios were 0.75, 0.61, 0.47 and 0.63 for the savannah, transition, forest zones and the pooled dataset respectively. Education was observed to reduce inefficiency of maize farmers across all three ecological zones. Farmer's age had a positive effect on technical inefficiency in the forest zone but had an adverse effect in the savannah and transition zones. Experience increased inefficiency in the savannah zone but reduced it in the two other zones while extension increased inefficiency in the transition zone but decreased it in the two other ecological zones. FBO membership decreased inefficiency in the savannah and transition zones but had a positive effect in the forest zone whereas land ownership increased inefficiency in the savannah zone but a negative effect in the forest and transition zones. The major occupation of the farmer had a negative effect in all zones while an available surplus market had a negative effect in the forest and transition zones but a positive effect in the dry savannah zone. Farmers from the transition and forest zones proved to be more efficient in their production than their counterparts from the savannah zone. This study recommends that maize producers in all three ecological zones increase the scale of production in order to increase output. Extension officers and other advisory services should endeavor to promote quality extension delivery that focuses on allocating inputs in optimal quantities to maximize output of maize farmers within each ecological zone.

TABLE OF CONTENT

DECLARATION	i
DEDICATION	ii
ACKNOWLEDGEMENTS	iii
ABSTRACT	iv
TABLE OF CONTENT	v
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF ACRONYMS	x
CHAPTER ONE	1
INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	3
1.3 Research Questions	5
1.4 Research Objective	6
1.5 Relevance of Study	6
1.6 Organisation of study	7
CHAPTER TWO	8
LITERATURE REVIEW	8
2.1 Introduction	8
2.2 Maize Production in Ghana	8
2.3 Measuring Productivity	10
2.4 Benefits of Technological Advancement and Organisational Change	12
2.5 Returns to Scale	13
2.6 Measures of Efficiency	13
2.6.1 Technical Efficiency	13
2.6.2 Allocative Efficiency	14
2.6.3 Economic Efficiency	16
2.7 Methods of Efficiency Estimation	16
2.7.1 The non-parametric approach	17
2.8 Parametric Frontier Analysis	18
2.9 The Stochastic Production Frontiers	19
2.9.1 The distributional assumptions of the stochastic frontier models	21
2.10 Functional Forms	23

2.10.1 The Cobb-Douglas functional form	23
2.10.2 Transcendental logarithmic function form.....	24
2.11 Determinants of inefficiency.....	25
2.11.1 The initial approach	27
2.11.2 Two stage approach	27
2.11.3 The single stage approach.....	28
2.12 The Stochastic Metafrontier.....	29
2.13 Farm Specific Factors	31
2.14 Constraint Methodologies	31
2.15 Empirical Results of Previous Technical Efficiency Studies.....	33
CHAPTER THREE	37
METHODOLOGY	37
3.1 Introduction.....	37
3.1.1 Conceptual Framework.....	37
3.2 Theoretical Framework.....	39
3.2.1 Stochastic frontier model	39
3.2.2 Stochastic Metafrontier Approach	43
3.3 Model Specification.....	47
3.4 Estimating Productivity	48
3.5 Returns to scale.....	49
3.6 Empirical Estimation of Technical Efficiency.....	49
3.7 Description of variables used in the frontier model.....	51
3.8 Empirical Model for the Determinants of Technical Inefficiency	52
3.9 Description and Measurement of factors that constitute the Inefficiency Model	53
3.10 Statement of Hypothesis	56
3.10.1 Statistical testing technique for the hypothesis	58
3.11 Analytical Software	58
3.12 Study Area	59
3.13 Data type, Sampling and Data Collection Methods.....	60
CHAPTER FOUR.....	63
RESULTS AND DISCUSSION	63
4.1 Introduction.....	63
4.2 Socioeconomic Characteristics of Farmers.....	63
4.3 Summary Statistics of Output and Input Variables.....	69
4.4 Results of Hypotheses tested.....	72

4.5 Productivity Estimates (Output Elasticity and Returns to Scale).....	74
4.6 Parameter Estimates of the Stochastic and Metafrontier Models	76
4.7 Summary on Technical Efficiencies (TE) and Environmental-Technology Gap Ratios (ETGRs) ..	78
4.8 Determinants of Technical Inefficiency.....	83
4.9 Constraints faced by maize farmers	88
CHAPTER FIVE	93
SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATIONS	93
5.1 Introduction.....	93
5.2 Summary of the Study	93
5.3 Conclusion	95
5.4 Policy Recommendations.....	97
REFERENCES:	98
APPENDIX.....	107

LIST OF TABLES

Table 3.1 Variables in Frontier Models	52
Table 3.2: Inefficiency variables and their a priori expectations.....	56
Table 4.1 Table of farmer-specific characteristics.....	64
Table 4.2 Socioeconomic characteristics of maize farmers by ecological zone.....	66
Table 4.3 Statistics of output and input variables	70
Table 4.4 Hypothesis test for group and metafrontier model	73
Table 4.5 Output elasticities and returns to scale from group and pooled frontiers	75
Table 4.6 Parameter estimates of the stochastic and metafrontier models	77
Table 4.7 Environmental-technology gap ratios and technical efficiency estimates.....	79
Table 4.8 Percentage distribution of Metafrontier technical efficiency scores	83
Table 4.9 Parameter estimates for the technical inefficiency model	84
Table 4.10 Constraints faced by maize producers in Ghana.....	90
Table 4.11 Table of test statistics.....	91

LIST OF FIGURES

Table 2.1 Distribution of maize production by region (2016).....	9
Figure 2.1 A Diagram Showing Allocative, Technical and Economic Efficiencies	15
Figure 3.1 Conceptual Framework	38
Figure 3.1 Metafrontier illustration.....	42
Figure 3.3 Ecological Zones in Ghana.....	62
Figure 4.1 Distribution of the meta-frontier technical efficiency scores	82

LIST OF ACRONYMS

AE	Allocative Efficiency
AEAs	Agricultural Extension Agents
AP	Average Product
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
ETGR	Environmental Technology Gap Ratio
FBO	Farmer Based Organization
MiDA	Millennium Development Authority
MoFA	Ministry of Food and Agriculture
METASIP	Medium Term Agricultural Sector Investment Plan
MFP	Multiple Factor Productivity
ML	Maximum Likelihood
MP	Marginal Product
NPK	Nitrogen, Phosphorous and Potassium
PFP	Partial Factor Productivity
RTS	Returns to scale
SFA	Stochastic Frontier Analysis
SFP	Single Factor Productivity

SRID	Statistical Research and Information Directorate
TE	Technical Efficiency
TFP	Total Factor Productivity
TGR	Technology Gap Ratio
TWT	Total Weighted Trees

CHAPTER ONE

INTRODUCTION

1.1 Background

“The importance of the agricultural sector in developing countries cannot be underestimated” (Yaro, 2013). Agricultural growth will be crucial for enhancing the livelihood of most of Africa’s poor. Most of Africa’s poor living in rural areas and urban areas will greatly depend on expanding agrarian profitability to raise their standard of living (Shan et al, 1997; World Bank, 2000). The African agricultural sector produces an average of 74% of its potential yield with the available technology (Nkamleu *et al.*, 2006). According to the Ministry of Food and Agriculture (MoFA, 2008), the agricultural sector is the backbone of the social and economic development of Ghana. The agricultural sector used to be the highest contributor to gross domestic product until the recent onset of oil production in Ghana. Agriculture in Ghana accounts for 19% of GDP (MoFA, 2011) and 75% of foreign exchange. “Most outputs of agricultural crops in Ghana are 20-60% below their achievable level” (Abdulai *et al.*, 2013).

The Maize crop (*zea mays*) is very essential to Ghana’s food security and also promotes the increase in farmers’ incomes via their engagement in its cultivation (Kuwornu et al, 2013). Maize is an important component for human diet and livestock feed in Ghana and also serves as a cash crop, hence ensuring improved production will enhance self-sufficiency among households (Wiredu *et al*, 2010). The sale of maize also provides a source of income which helps improve the standard of living of maize producers in the different ecological zones in Ghana. Maize is the leading crop with regards to cropped area, accounting for about 50% of national cereal production according to the Millennium

Development Authority (MiDA, 2010). The total cropped area for maize in the 2016 production year was 865,281 hectares according to Statistical Research and Information Directorate of MoFA (SRID, 2017). According to MiDA (2010), “after cocoa maize is the second largest commodity crop in the country and is most important crop for Ghana’s agricultural sector”. Maize is a major component of poultry feed and is highly demanded by poultry feed manufacturers (Ravindran, 2012).

According to SRID (2017) “the yield of 1.9 Mt/ha for maize is less than a third of the potential yield of 6.0 Mt/ha”. Increased agricultural growth needs to be propelled by enhanced productivity rather than land expansion (Nkamleu *et al.*, 2006). “The total harvested area for maize increased by 45% between 1970 and 2009 with an average cropped area of 930,000 ha per year” (SRID/MoFA, 2010). There is potential for growth by increasing productivity in Ghana. This is evident in the gaps that exist between current and potential yields of many crops. “The main cause of low productivity in maize farming include overutilization of unimproved maize seeds, reduction in soil fertility, inconsistent rainfall, pests and disease attacks, little improvement in agronomic practices and limited use of output-increasing inputs like agrochemicals and fertilizers” (Serunkuuma *et al.*, 2001). (Zhou *et al.*, 2010) found that education helps farmers to gain better information about new technologies like new inputs of production and how to use them to increase their output. Other variables that may affect productivity may include competitive pressure and managerial skills (Kumbhakar *et al.*, 2000).

Technical efficiency basically calls attention to the capacity of a producer to maximize yields with a specified group of inputs whereas environment-technology gap refers to the various sets of production processes that are available to producers in different ecological

zones. The aim of Ghana's Medium Term Agriculture Sector Investment Plan (MoFA, 2010) is to modernize agriculture which will bring about a transformed economy which is food secure, with low poverty and employment rates. The ability of maize farmers in Ghana to increase their yield levels and achieve sustainability in production is dependent on efficient farm practices. Increasing agricultural productivity is essential to poverty reduction and will also help to reduce the cost of production and the prices of food for the poor.

Contrasts in technical efficiency are seen as contrasts in the physical yield created from a given set of physical input sources. Factors such as climate change and natural disasters, poor road networks, inadequate post-harvest technology, rural urban migration, constant increase in demand for land and other factors make it necessary for a nation like Ghana to want to look at its efficiency with regards to agricultural production, particularly food staples such as maize.

1.2 Problem Statement

The aggregate factor productivity in the agricultural sector can be enhanced either by enhancing technical effectiveness and additionally by enhancing innovation levels. "An important inquiry for agricultural policymakers is whether to seek after a technique coordinated towards mechanical change or a methodology towards efficiency change" (Nkamleu *et al.*, 2004). The domestic supply of maize in Ghana is reported to be below the growing demand despite the importance of maize to the Ghanaian economy (MiDA, 2010). The production of maize in Ghana is a primary undertaking of small scale farmers who have limited access to the use of improved seed, fertilizer, other chemical inputs,

mechanization and post-harvest facilities. Ghana continues to observe a decline in production even though the government has made a lot of investments in the sector due to decreasing familiarity with improved technologies.

Constant increases in human populations have led to a substantial increase in demand for arable agricultural land for human settlements in many parts of the country (Jimah, K. 2016). This has created rivalry for the utilization of limited land resources for either agricultural production or real estate development for human settlements and other business activities. In an attempt to increase agricultural outputs, excessive use of chemical inputs degrades the natural environment overtime and eventually renders land used for cultivation infertile and unable to support plant growth. Conventional increases in production outputs are normally attained by an increase in cropped land but this activity is constrained by increasingly scarce land availability. How farmers adapt to these changes and how they will manage to meet the ever growing demand for maize ultimately depends on the efficient use of production resources on the farm.

The existence of shortfalls in the technical efficiency of production implies that yields can be increased without requiring additional conventional inputs and without the need for new innovation. Belbase and Grabowski (1985) realized that attempts to raise efficiency levels as a strategy to increase agricultural output is cheaper than presenting new advances if producers are not streamlining the utilization of existing ones. Temperature, rainfall and other climatic factors that affect maize production differs across the different ecological zones within the country. Certain ecological zones may be more suited to the ideal conditions required for maize production than others. If so, empirical measures of effectiveness are essential so as to decide the extent of the benefit that could be attained by

enhancing performance with an accessible innovation. In the sight of environmental-technology gap, technical progress, is the judicious technique to fundamentally raise the levels of agricultural output (Nkamleu *et al*, 2006).

It is important to study maize producers to determine their highest yield potential given available technologies and limited land resource, and to identify spatial/geographical differences in order for policies to be tailored to how different parts of the country can improve upon their yield. This study aims to identify and explain the determinants of inefficiencies in production which are not likely to be the same across the different ecological zones. Hence the need for empirical studies that measure and compare technical efficiencies and environmental-technology gaps present in the maize sector in three different ecological zones in Ghana. The specific ecological zones include the savannah zone, the transition zone and the forest zone. This study will give an insight to the elasticity of output with respect to the main inputs of maize production in the three selected ecological zones. The study will also identify the determinants of inefficiency within those ecological zones in order for tailored policies to be directed at addressing the results observed from this study. To the best of available knowledge, no empirical study has addressed this issue. This research seeks to fill the void.

1.3 Research Questions

From the above discussions, this thesis would want to address these questions:

1. What is the elasticity of output with respect to the various inputs in maize production?
2. What are the levels of technical efficiency across the three ecological zones?

3. What are the environmental-technology gap ratios in maize farming in the three selected ecological zones?
4. What are the causes of inefficiency in maize production?
5. What are the constraints faced by maize farmers in the three ecological zones?

1.4 Research Objective

The main objective of the study is to comparatively analyze the technical efficiency levels and technology gaps in maize production in selected ecological zones.

The specific objectives are:

1. To estimate the output elasticity with respect to the various input in maize production in the selected study areas.
2. To estimate the technical efficiency scores for each ecological zone.
3. To compute the environmental-technology gap ratios of maize production in the three ecological zones.
4. To identify and explain the causes of inefficiencies in maize production.
5. To identify the constraints faced by maize farmers in the three ecological zones

1.5 Relevance of Study

This study seeks to estimate the productivity of input factors to maize output and provides insight about the relationship of the various input factors to output and the extent to which output will change if the input factors are changed. The estimated scale elasticity of production provides an indication of the change in output if all the factor inputs are varied by the same proportion in the long run. The estimates derived help to inform policy on the right input mix which will result in increased output in the three ecological zones.

Identification of factors that improve efficiency is a very important step to give policy recommendations. The identification of existing inefficiencies and constraints will help farmers and all other stakeholders develop strategies targeted at reducing production inefficiency. This study is also aimed at computing the environmental technology gap that exists in the maize sector in the three main ecological zones in Ghana. The standard technical efficiency estimates and environmental technology gap ratios that are estimated with the aid of the Metafrontier model will inform policy makers on how far each ecological zone is from the best practice technology available to the whole maize industry. This will help policy makers design tailored policies for each ecological zone with regards to the kind of training and technology that farmers must adopt and the utilization of the best agricultural practices within each ecological zone.

1.6 Organisation of study

This thesis is divided into five chapters. Chapter one contains an introduction to the background of maize production in Ghana and the importance of technical efficiency in production. It also contains the problem statement, the study objectives, and the significance of this study. The second chapter contains a review of literature on measures of productivity and efficiency and discussions of previous empirical studies related to this research. Chapter three describes the conceptual and theoretical underpinning of this thesis. Chapter four gives a detailed discussion on the observed results and the fifth chapter contains a brief on the study's final conclusions and proposed policy recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter of the study provides a review of literature which is relevant to this study. Definition and explanation of concepts and terms are used in this study are provided. Adequate literature on the theoretical underpinnings and methodologies used in measuring productivity and efficiency estimation are reviewed. Empirical applications and results of other studies are also reviewed in this chapter.

2.2 Maize Production in Ghana

Maize production in Ghana is mainly undertaken by small scale farmers. Most farmers follow conventional practices that are subject to rainfall conditions, consumption trends and largely influenced by various input requirements. The major food crops cultivated for domestic consumption include maize, sorghum and millet while on the other hand groundnut, cowpea, rice, soybean and yam are cultivated for sale (Wiredu et al. 2010). National statistics indicate that, significant quantities of maize produced in the country are cultivated on about 865,281 hectares of land and yields an average of about 1,721,910 metric tonnes per annum (SRID, 2017). Cultivation of maize is undertaken in all ten regions of Ghana but an estimated 70% of all maize output is obtained from five regions and these are the Northern, Brong-Ahafo, Ashanti, Central and Eastern regions of Ghana (Amanor-Boadu, 2012). According to Table 2.1, SRID reported that average yields of maize per hectare in Ghana stand at 1.99 metric tonnes with a potential to achieve 6.0

metric tonnes/hectare. The distribution of maize production in Ghana for the year 2016 is captured in the table below.

Table 2.1 Distribution of maize production by region (2016)

Region	Cropped Area	Yield (MT/Ha)	Output
WESTERN	49,170.00	1.48	72,994.00
CENTRAL	78,843.00	2.23	175,890.00
GREATER ACCRA	3,062.00	1.20	3,687.00
VOLTA	52,275.00	1.88	98,223.00
EASTERN	150,723.00	2.70	407,052.00
ASHANTI	122,256.00	1.65	201,186.00
BRONG AHAFO	213,042.00	1.90	405,641.00
NORTHERN	91,108.00	1.97	179,416.00
UPPER EAST	43,840.00	1.42	62,383.00
UPPER WEST	60,962.00	1.89	115,438.00
AVERAGE	865,281.00	1.99	1,721,910.00

Source: SRID (2017)

The per capita consumption of maize in Ghana exceeds that of other cereals (rice, wheat, sorghum and millet) and stands at a value of 45.0 kg/year. These is adequate proof of the importance of maize as food security crop in Ghana. It is the main source of income of producers in the maize surplus regions and is cultivated in all the agro-ecological zones under mono-crop or intercrop systems (Kibaara, 2005). The production of maize in Ghana is usually constrained by certain factors, some of which include drought during early stages of growth, low soil fertility, pest and diseases, poor management practices, wrong planting time, inadequate weed control, limited input use, lack of credit, untimely fertilizer application, inadequate drying and storing facilities which leads to post harvest losses, poor access to market and a lot more (Adu et al. 2014).

2.3 Measuring Productivity

Productivity is basically defined as the total output obtained per the quantity of inputs allocated to the production activity. This can be measured in terms of marginal productivity (MP) (the rate at which output changes per unit change in input employed). It can also be measured in terms of average productivity. The average product (AP) can also be referred to as the partial factor productivity (output per labour, output per land). These are mathematically expressed as:

$$AP = \frac{Q_i}{X_i} \quad (2.1)$$

$$MP = \frac{\partial Q_i}{\partial X_i} \quad (2.2)$$

A variety of approaches have been used by different researchers for varying reasons. Productivity is measured as the ratio of total output of a farm to a measure of inputs used in production (Gordon *et al.* 2015). Single factor productivity (SFP) only considers the contribution of one input to the total output obtained. In contrast, total factor productivity (TFP) considers an aggregation of all the inputs employed to produce the total output. The SFP and TFP are both expressed as:

$$SFP = \frac{Q}{X_i} \quad (2.3)$$

$$TFP = \frac{\sum_{i=1}^n Q_i}{\sum_{i=1}^n X_i} \quad (2.4)$$

Where Q is the total output produced and X_i represents the level of input i committed to the production process.

Finally, Multiple Factor Productivity measures economic performance by comparing the quantity of output produced to the quantity of total inputs employed to produce that output. This can be expressed as:

$$MFP = \frac{Y}{\sum_{i=1}^n X_i} \quad (2.5)$$

Where the X_i 's represent the various inputs.

Multi Factor Productivity is a broad measure of technological progress that comprises of improvements in the organisation of the process of production, the use of information technology and advances in technology etc. (Powell, 2012). The marginal physical product(MPP) for any input resource employed in the production process is the value of the initial derivative of the production function. The MPP is expressed as:

$$MPP_i = \frac{\partial TPP_i}{\partial X_i} \quad (2.6)$$

The marginal physical product is positive if and only if the restriction of monotonicity holds for the i th input, but it must be acknowledged that in reality, the production process requires optimal combinations of different inputs, therefore the employment of one variable input with others held constant only leads to increments in output to a certain limit after which the MPP falls (Otieno, 2011). When TPP is at its highest the MPP reaches zero,

however, this does not necessarily imply that efficiency has been attained. Coelli *et al.*, (2005) opined that, efficiency may only be achieved at a point where the marginal product value equals the marginal cost for each input employed. The second order condition for optimization is satisfied and the gradient of the marginal product curve is negative which means that aside being positive, the marginal products should be decreasing in inputs (Henningson and Henning, 2009).

The non-frontier and the frontier approach are the two main approaches to the estimation of TFP. With the frontier approach, the estimation depends on the production function but whereas in the non-frontier approach it's not.

2.4 Benefits of Technological Advancement and Organisational Change

Innovation is the most important driving force for growth in farm level productivity. Through the adoption and use of efficient technologies and management practices, farmers are able to minimize their cost of production (Gray *et al.*, 2014). Firms' efficiency in production can be improved if they innovate and apply new technologies or methods that are directed at expanding output level beyond additional inputs required or by adopting technologies and organisational structures that are new to the firm (Gordon *et al.* 2015). This shifts the production possibility frontier outward because technological change allows the firm to increase output with lower input levels. Castanheira and Leppamaki (2013) opined that either through organisational structure or through improved technologies or a combination of these, firms are able to increase their level of productivity.

2.5 Returns to Scale

Returns to scale measures the responsiveness of yield to a proportional increase in all inputs in the long run (Otieno, 2011; Coelli et al. 2005). Changes in output which are caused by proportional changes in all input levels is technically referred to as returns to scale. If the change in output is equal to the proportional change in input, then it is regarded as a constant return to scale. If output is raised by less than the proportional rise in all input levels, then it is regarded as a decreasing returns to scale but if output levels are raised by more than the proportional increase in all inputs the we observe an increasing return to scale. Total elasticity of production or the elasticity of scale is another way to refer to returns to scale and this is expressed as:

$$RTS = \frac{MPP}{APP} \quad (2.7)$$

2.6 Measures of Efficiency

According to Farrel (1957), efficiency measurements are decomposed into two categories namely the Technical Efficiency (TE) and Allocative Efficiency (AE). The multiplication of the Technical efficiency by the Allocative Efficiency yields the Economic efficiency.

2.6.1 Technical Efficiency

Technical efficiency can be defined as the ability of an agent of production to maximize yield levels from an available set of inputs with a specified set of technologies. It is the connection between what an association or a producer manufactures and what it could plausibly deliver, under the supposition of full use of the assets available (Garcia del Hoyo et al., 2004). Therefore, technical inefficiency is observed when a production unit is unable to meet its highest potential yield with a specified range of input resources. This

measurement deals with the comparison of actual performance of a farm to the optimal performance (Bempomaa and Acquah, 2014).

Input use efficiency and productivity are influenced by the technology being adopted, labour employed, level of capital utilisation, level of skills and knowledge both technical and managerial (Okezie and Okoye, 2006). The production frontier is therefore the highest possible yield that can be attained with a specific set of input resources and the prevailing production innovations. It explains technical efficiency by relating it to the least amounts of resources needed for the production a specified amount of yield. If a production agent is unable to produce what he could have produced, it simply means he is operating below the frontier. The space that separates the producer from the production frontier measures his inefficiency (Garcia del Hoyo *et al.*, 2004). TE is also expressed as the proportion of obtained yield (Q_i) to the highest attainable yield (Q_i^*).

$$TE = \frac{Q_i}{Q_i^*} \quad (2.8)$$

2.6.2 Allocative Efficiency

Allocative efficiency on the other hand is the ability of a producer to use inputs in optimal proportions given their respective prices. It is also known as price efficiency. A firm is seen as being allocatively efficient if the value of an inputs marginal product is equal to the price of the input. In other words, a combination of inputs is chosen to produce a set quantity of output at a minimum cost. This concept is explained in Diagram 2.1. Farrell (1957) assumes a constant return to scale (CRS) and the unit isoquant YY' fully describes the technological set that captures the minimum combination of inputs required to produce a unit of output. Hence, every combination of inputs along the unit isoquant is considered as technically

efficient whilst any point above and to the right of the isoquant, such as point G, indicates a technically inefficient producer. This is because, more than enough of the input combination is being used to produce a unit of output.

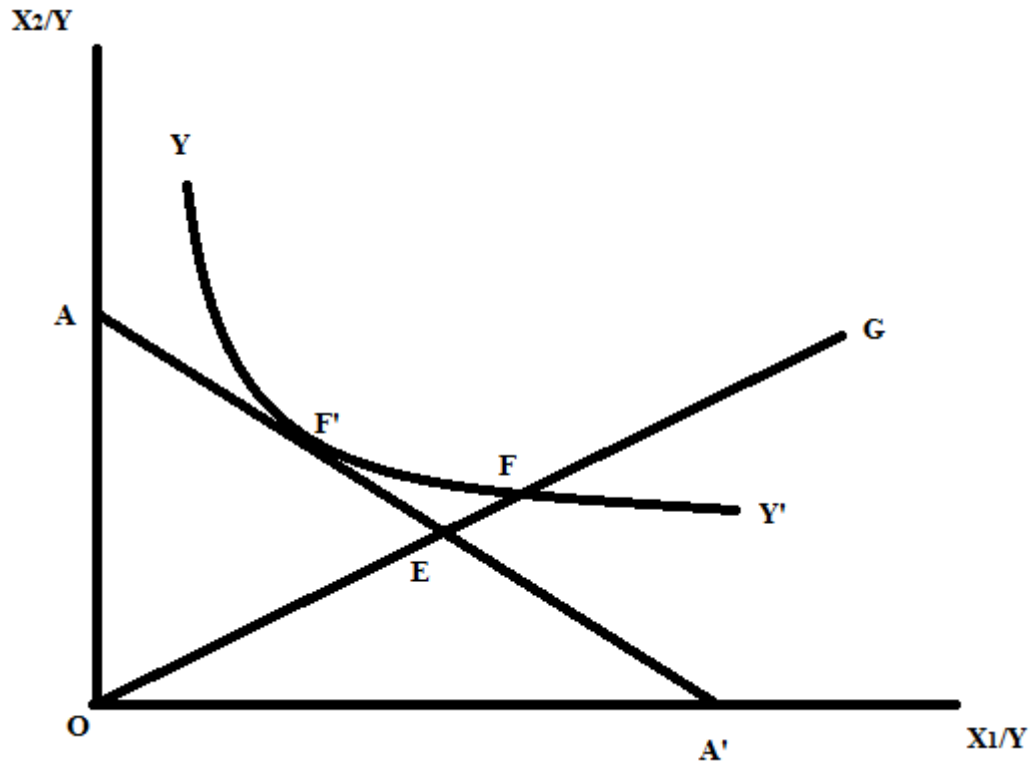


Figure 2.1 A Diagram Showing Allocative, Technical and Economic Efficiencies

Source: Murillo-Zamorano (2004)

Hence, the technical inefficiency of the producer at G is measured along the distance FG. The technical inefficiency of the producer at G can be expressed as FG/OG , hence, its corresponding technical efficiency (TE) is given as $(1-FG/OG)$ or further simplified as OF/OG . When information on market prices are known, allocative inefficiency can also be derived from the isoquant in the graph given above. Therefore, for the estimation of

allocative inefficiency, the relevant distance is indicated by the line segment EF, which would be given as the ratio EF/OF. The allocative efficiency (AE) that defines the producer at point G is given by the ratio OE/OF.

2.6.3 Economic Efficiency

Farrell (1957) describes Economic Efficiency as an overall efficiency, which encompasses the multiplication of the technical and allocative efficiency of a firm and is expressed as:

$$EE = TE * AE \quad (2.9)$$

Economic efficiency is observed when a farm selects inputs and enterprise in order to optimize their economic gain. Technical and Allocative efficiency are on their own necessary conditions for measuring the productivity of a farm but are not sufficient conditions to obtain efficiency in production. Variations in economic efficiency among different farms may prevail due to differences in their technical or allocative efficiency (Yotopoulos *et al.*, 1973). Efficient frontier measurement is categorized into either parametric approach or non-parametric approach.

2.7 Methods of Efficiency Estimation

The parametric and non-parametric approaches are the two main methods of efficiency estimation

The non-parametric frontier technique which has been incorporated into the Data Envelopment Analysis (DEA) which was developed by Farrell (1957) and Charnes *et al.* (1978). The methods used in constructing the efficient frontier are based on mathematical programming. It also uses the calculus of efficiency scores relative to those constructed frontiers.

The parametric approach was designed by Aigner et al. (1977) and Meeusen *et al.* (1977) in the context of the deterministic frontier and stochastic frontier approaches.

2.7.1 The non-parametric approach

Farrell (1957) developed the Non-parametric frontier approach to efficiency estimation which has been extended by Charnes et al. (1978) as well as Fare, Schmidt & Lovell (1986) to include multiple output- input technologies. The approach has traditionally been absorbed into Data Envelopment Analysis (DEA) which is mathematically not demanding as compared to the parametric approach. Data envelopment analysis (DEA) is a procedure for estimating the relative performance of production units based linear programming where the existence of more than one input and output makes comparisons tough. DEA is a relatively new “data oriented” approach for assessing the execution of group of production agents called Decision Making Units (DMUs) which transform different inputs to various yields. The meaning of a DMU is non-specific and adaptable. The empirical orientation of DEA and its requirement of very few a priori assumptions which is contrary to other approaches have resulted in it being a primary choice for quite a number of studies that involve the estimation of efficient frontiers in the regulated sector, in the private sector and also in the government and non-profit sector. Originally, DEA was explained by Charnes *et al.*, (1978) as a “mathematical programming procedure applied to observational data that gives a new avenue to acquiring empirical estimates of relations - such as the production functions and/or efficient production possibility surfaces – that are the pillars of modern economics”.

The DEA methodology is usually directed to frontiers but not central tendencies. Statistical regressions attempt to fit regression planes through the centre of datasets but in DEA, a

smooth linear curve is constructed to lie above the observations. Due to this idea, DEA is able to uncover relationships that other methodologies are incapable of. If we consider what we mean by “efficiency”, or more generally, why we may consider one DMU to be more efficient than another DMU. This is estimated directly in DEA without the need for clear-cut assumptions and variations with different models like in nonlinear and linear regression models.

2.8 Parametric Frontier Analysis

Farrell’s theory was improved upon by Aigner and Chu (1968) who used the deterministic approach to measure technical efficiency. They achieved this by using linear programming to compute a deterministic Cobb-Douglas production frontier in order to obtain technical efficiencies. The deterministic approach associates all displacements away from the efficient frontier to the producer, as a result any resulting deviations are regarded as technical inefficiency. Hence the effect of random noise is not accounted for. The parametric frontier approach defines the functional form of the efficient frontier and uses either cross sectional data or panel data for technical efficiency analysis (Aigner et al., 1977). The approach imposes restriction on production function but allows for statistical inferences that can be tested as well as different hypotheses on the parameters that are estimated for the production frontier.

The parametric frontier analysis is categorised into deterministic and stochastic (Kibirige, 2008). The deterministic production frontier assumes that any deviations (due to bad weather conditions, socio-economic factors and uncertainties) from the fully efficient production frontier are within the influence of the farmer and are considered as inefficiency (Constantin et al., 2009). The principal disadvantages with the deterministic frontiers are

that, any measurement errors, approximation errors, specification problems and other sources of variation in output are associated with inefficiency while the stochastic frontier model captures the consequence of shocks that are unplanned to the production frontier (Al- Hassan, 2012).

The deterministic frontier is estimated either by mathematical programming or econometric approach whilst the stochastic uses the econometric technique only. Another problem of the parametric approach under mathematical programming is that the estimates are highly responsive to outliers and measurement errors since the estimates are supported from a subset of data. The disadvantages of the parametric technique under linear programming are overcome by using econometric techniques of estimation in the deterministic and stochastic frontier approaches.

2.9 The Stochastic Production Frontiers

The Stochastic Frontier Production model originated from works done by economists such as Meeusen and van den Broeck (1977), Aigner *et al.*, (1977) and Battese *et al.*, (1977). This model has the error component which is separated into the random component and inefficiency effect. Hence, this approach to technical efficiency analysis seeks to explain that displacements away from the highest possible output may be due to other additional external factors other than only from the inefficiency of the production agent. Other factors which contribute to variations may be external shocks outside the control of the producer (Kebede, 2001). These random or external shocks include effects of weather as well as diseases, economic and institutional shocks, population growth and other uncertainties.

The stochastic frontier function can be written as;

$$Q_i = f(X_i; \beta) \cdot \exp(v_i - u_i) \quad (2.10)$$

Where:

Q_i = output of the i^{th} farm

X_i = the quantity of vector inputs for the i^{th} farm;

β = the unknown coefficients to be estimated;

v_i = the random effects

u_i = a non-negative error component that measures the endogenous sources of technical inefficiency effects on the part of the producer.

The composed error term is $\varepsilon_i = v_i - u_i$, where v_i captures the effect of pure noise in the data attributed to measurement error, extreme weather conditions etc. and the one-sided inefficiency effects are denoted as u_i . A single firm's technical efficiency from the stochastic frontier is expressed as a proportion of the actual output to its own analogous stochastic frontier output, with respect to the input levels used by the firm. Therefore, a firm's technical efficiency using the function of the stochastic production frontier which is given by;

$$TE = \frac{f(X_i; \beta) \cdot \exp(v_i - u_i)}{f(X_i; \beta) \cdot \exp(v_i)} = \exp(-u_i) \quad (2.11)$$

2.9.1 The distributional assumptions of the stochastic frontier models

We take a look at the distributional assumptions of v_i and u_i . The v_i 's are assumed to be independent of the u_i 's with the two terms uncorrelated with the explanatory variables. Making sure there is consistency with the conventional classical assumption, the v_i and u_i are given as:

$E(v_i) = 0,$	Zero mean
$E(v_i^2) = \sigma_v^2,$	Homoskedastic
$E(v_i v_k) = 0,$ for every $i \neq k,$	Uncorrelated
$E(u_i^2) = \text{Constant},$	Homoskedastic
$E(u_i u_j) = 0$	Uncorrelated

Based on the assumptions of v_i 's and the u_i 's, then estimates from the Ordinary Least Square can be used for the model. But with this, the coefficient of the intercept term which is biased downwards can be corrected by applying the least square estimator. The use of the maximum likelihood method of estimation gives a better solution under certain distributional assumptions of the two error terms using iterative optimization routines.

Assuming the random component v_i 's are said to have a distribution which is independent and identical with a zero mean and constant variance and the u_i 's may be distributed in any of the following ways as independent pure noise:

Half Normal: $U_i \approx iidN^+(0, \sigma_u^2)$

Truncated Normal: $U_i \approx iidN^+(\mu, \sigma_u^2)$

Exponential: $U_i \approx iidG(\lambda, 0)$

Gamma: $U_i \approx iidG(\lambda, m)$

The distributional specification with respect to the u_i 's is sometime a matter of computational convenience. The half-normal and exponential distribution assumes that most inefficiency effects are in the range of zero, which is connected with technical efficiency approaching 0. The gamma together with the truncated normal models permit the use of distributional shapes on a wider range, but this makes the computation quite complex, since this increases the parameters that need to be estimated and the probability distributional functions for v_i 's and u_i 's may possess shapes that look alike which can make it hard to differentiate random errors from inefficiency effects.

According to the premises proposed for the random errors, the observed output of the farm has a log likelihood function which is expressed by Aigner et al. (1977) as:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad (2.12)$$

$$\lambda = \frac{\sigma_u^2}{\sigma_v^2} \quad (2.13)$$

This parameterization is limited because the variance σ_u^2 refers to the variance of the truncated random variable instead of the truncated half normal model.

The estimates of the frontier model are specified by the maximizing of the appropriate log likelihood function. These estimates are useful in validating the appropriateness of the inefficiency model. The inefficiency is assumed to have a half-normal distribution, that is

$U_i \approx iidN^+(0, \sigma_u^2)$. Information on the variable U_i is conditioned on the composed error term. This was used to derive the predictor of U_i and $1 - E(U_i | V_i - U_i)$ was further used to compute the technical efficiency of the i -th farm. The U_i 's were also estimated in the case of exponential distribution of the one-sided error term.

However, the best way to estimate the technical efficiency of the i -th farm which is expressed as $TE = \exp(-u_i)$ can be done by using the conditional expectation of $\exp(-u_i)$, with $E_i = V_i - U_i$ the random variable since it is consistent with the technical efficiency definition. Battese and Coelli (1995) opined with their findings on the truncated distribution with mean, u_i dependent on the exogenous variables and the input variables contrary to the half-normal distribution. Greene (1980) dealt with the shortfall associated with the half-normal and exponential cases with the two parameter gamma distribution he proposed.

2.10 Functional Forms

The most widely used functional forms employed by researchers for estimating production frontiers include the Cobb-Douglas functional form and the translog functional forms. Each possesses its own advantages and disadvantages are selected based on how best they suit a particular study.

2.10.1 The Cobb-Douglas functional form

The Cobb-Douglas Production Function is expressed as:

$$\ln Y_i = \beta_o + \sum_{k=1}^N \beta_k \ln X_k + \varepsilon_i \quad (2.14)$$

Knut Wicksell, proposed this model which was later used by Charles Cobb and Paul Douglas against statistical evidence in 1900-1928 as cited in Shen *et al.* (2012). This model is appropriate for analyses and usually involves the estimation of fewer parameters. It has inherent advantages which makes it preferred for analysis. Some of these include, the ability to handle different kinds of econometric estimation problems some of which include multicollinearity, serial correlation and heteroscedasticity in a much easier and adequate way (Ogujiuba *et al.*, 2014). Another ability this model has is how it facilitates computations and has the properties of explicit representability, uniformity and flexibility. Finally, the elasticities of each input estimated by this model can be easily obtained and interpreted (Ilembo *et al.*, 2014) and less data demanding. A major disadvantage that arises is that, all firms are assumed to have production elasticities that are equal and with an elasticity of substitution equal to one.

2.10.2 Transcendental logarithmic function form

This functional form is specified as:

$$\ln Q_i = \ln \beta_o + \sum_{i=1}^n \beta_i \ln X_i + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \beta_{ij} \ln X_i \ln X_j + (v_i - u_i) \quad (2.15)$$

The translog is usually referred to as a flexible functional form. Just as in the case of the Cobb-Douglas functional form, the translog also has inherent advantages. It was developed through research to define new flexible forms of production functions that ensure the approximation of constant elasticity of substitution in production functions. The flexible nature of the translog functional form provides fewer restrictions on production elasticities and substitution elasticities. It also gives an approximation of the second-order to any underlying function. However, one setback is the fact that, this flexible functional form

estimation requires a larger sample size, which is always not possible. Moreover, there can be instances of multicollinearity with regards to translog model between the regressors which has the probability of giving wrong estimates for the model parameters (Daghbashyan, 2011). Though the translog is considered as quite more cumbersome in terms of interpretation, it needs the incorporation of a lot of parameters than the Cobb-Douglas production function.

2.11 Determinants of inefficiency

The stochastic frontier model proposed by Aigner *et al.*, (1977) assumes that a production frontier is available at a specific time which represents the averages of best practice production given the prevailing technology and current level of inputs (Asche and Roll, 2013). This procedure specifies the error component as being composed of two constituents, a normal and a one-sided distribution. The incorporation of exogenous variables brings about differences in technical efficiency levels and an understanding of this will enable policy makers formulate policy directives toward the achievement of the frontier output at a given technology and input level (Coelli and Battese, 1996). Some of the exogenous variables may include the following: farmers age, level of education of the farmer, access to credit by the farmer, extension services, experience, farm distance etc.

The basic model is expressed as:

$$\ln y^* = f(x_i; \beta) + v_i \quad (2.16)$$

Where $\ln y^*$ represents the stochastic frontier for observation i ; $x_i; \beta$ represents the technology; x_i is the vector of input variables; β represents the parameter vector to be

estimated; v_i is the statistical noise assumed to be $N(0; \sigma_{v_i}^2)$. In other words, it is assumed to have a normal distribution with a zero mean and a constant variance. This frontier model is assumed to give the efficient level of output or the best practice production.

Aigner et al. (1977) proposed that, inefficiency is introduced into the model by constructing a new composite error term in which the identification of estimates of efficiency is done separately from the usual stochastic noise. The expression below specifies the stochastic production frontier with inefficiency:

$$\ln y_i = (x_i; \beta) + \varepsilon_i \quad (2.17)$$

$$\varepsilon = v_i - u_i \quad (2.18)$$

The ε is composed of the error term and includes the v ; the random error with zero mean and the u ; the production inefficiency effect. The v has a normal distribution with a zero mean and the u follows a half-normal distribution. Battese and Coelli postulated that determinants of technical inefficiency could be found by setting u_i as a function of other exogenous variables such as socioeconomic characteristics of a farmer. u_i could be set as a half normal distribution where $u_i \sim N^+(0, \sigma^2)$. It leaves σ^2 as the only variable to be parameterized and the heteroscedasticity problem of u_i is translated to show the determinants of inefficiency as:

$$\sigma_i^2 = \exp(z_i; w) \quad (2.19)$$

Where z_i represents the variables that possibly have an influence on the efficiency while w is a parameter vector. The coefficient sign shows the direction of the impact of the exogenous factor on the $E(u_i)$; a positive value simply means the variable has a high level of inefficiency and a negative value means the variable has a low level of inefficiency. The slope coefficients do not give us the magnitude of the inefficiency because the relationship

that prevails between the $E(u_i)$ and the z_i in a non-linear one (Asche and Roll, 2013). A number of approaches have been adopted to incorporate the exogenous variables into efficiency measurement models. A few of these are given attention below.

2.11.1 The initial approach

In this technique, exogenous variables are fused as part the frontier model on the assumption that they have an effect on the output of production. The stochastic frontier is given as:

$$\ln Q_i = \ln f(x_i, z_i, \beta) + v_i - u_i \quad (2.20)$$

Where Q_i , x_i , z_i and β denote the output, input vectors, vectors of exogenous variables and production parameters to be estimated respectively. In this formulation, the exogenous variables are assumed to have a direct effect on output by altering the nature of the production frontier relative to which the efficiency of producers is estimated and not the efficiency itself. Differences in efficiency are left unexplained in this technique due to the assumption that the exogenous variables are not correlated with each noise term of v_i and u_i .

2.11.2 Two stage approach

Kumbhakar and Lovell (2000) linked the differences in estimated efficiency with that of exogenous factors in two stages. In the first stage, a stochastic frontier devoid of exogenous variables is estimated based on the assumed hypothesis. In the second stage, the estimated inefficiency effects are regressed on all the exogenous variables that were hypothesized to influence the efficiency of the producer. The general formulation is specified as:

$$E(u_i | v_i - u_i) = g(z_i; \gamma) + \varepsilon_i \quad (2.21)$$

Where $\varepsilon_i \sim iidN(0, \sigma_\varepsilon^2)$; γ is the parameter to be estimated. The assumption on which this approach is based proposes that z_i influences y_i through an estimated efficiency. The variation in efficiency in this approach is explained as against the initial approach. The major disadvantage of this approach stems from the presumption of independent identical distribution of inefficiencies from the initial step which is then flouted in the second. This occurs when anticipated efficiencies are accepted to have a utilitarian association with the external factors. Also it has been assumed that elements of the inefficiency variables and the input variables are uncorrelated, however in the case that they are correlated, the MLE of the stochastic production frontier is biased since an important variable z_i is omitted in the first stage (Kumbhakar and Lovell, 2000).

2.11.3 The single stage approach

In this approach the effects of inefficiency are explained to be an explicit part of certain characteristics peculiar to the firm as proposed by Kumbhakar et al. (1991) and Reifschneider et al. (1991). The coefficients in the inefficiency model and those of the frontier are computed with the maximum likelihood procedure in a single stage. This helps explain the difference in inefficiency and avoids the problem of identical distribution. The advantage of this procedure is that it maintains the presumption of identical distribution of the inefficiency error component. For this reason, the single stage approach was adopted by Onumah et al. (2010), Binem et al. (2008) and Battese et al. (1995) for analysing the determinants of inefficiency.

The inefficiency model explained by socio-economic factor can be expressed as:

$$\mu_i = Z_i \delta \quad (2.22)$$

Z_i represents a set of socio-economic factors that influence technical inefficiency while δ denotes a set of unknown parameters.

2.12 The Stochastic Metafrontier

The meta-production was initially developed by Hayami (1969). According to Hayami et al., (1971), “The meta-production function can be regarded as the envelope of commonly conceived neoclassical production functions.” The concept of the meta-production function is theoretically appealing due to the fact that it is based on the assumption that every producer, irrespective of the group they belong have equal potential access to the same technology. The stochastic meta-frontier model possesses an error term that is decomposed into a symmetric random noise and a technical inefficiency term which is non-negative like the stochastic production frontier model, developed by Aigner et al., (1977). Non-stochastic approaches can also be used to construct metafrontier functions.

Let’s assume that outputs and inputs of various firms in a determined industry are stated with the end goal that stochastic frontier production functions are established for diverse groups in that industry. We could assume that there are a number of well-established groups for that industry, for instance diverse types of ownership, different ecological zones within a country, or ethnic groups involved in production. Assume that, for the j th group, there are test information on N_j firms or producers that create one yield from the different input sources and the stochastic frontier model for this group is characterized by,

$$Y_{ij} = f(x_{ij}, \beta) e^{V_{ij} - U_{ij}}, \quad i = 1, 2, \dots, N_j \quad (2.23)$$

where Y_{ij} is the yield for the i th firm in the j th group; x_{ij} speaks to a vector of elements of the sources of inputs utilized by the i th firm in the j th group; the V_{ij} s are thought to be identically and independently distributed as $N(0, \sigma_v^2)$ arbitrary factors, autonomous of the U_{ij} s, which are characterized by the truncation (at zero) of the $N(\mu_{ij}, \sigma^2)$ distributions, where the μ_{ij} s are characterized by some fitting inefficiency model. The subscript j is left out after this stage for simplicity in order for the j th group model to be expressed as:

$$Y_i = f(x_i, \beta) e^{V_i - U_i} \equiv e^{x_i \beta + V_i - U_i} \quad (2.24)$$

The equation above presumes that the exponent of the production frontier function has a linear parameter vector of β , so that x_i is a vector of elements of logarithms of the contributions for the i th firm. Therefore, all firms in all the different groups of the industry have a stochastic meta-frontier model which is given as:

$$Y_i = f(x_i, \beta^*) e^{V_i^* - U_i^*} \equiv e^{x_i \beta^* + V_i^* - U_i^*} \quad (2.25)$$

Where $N = \sum_{j=1}^R N_j$ refers to the total sample of firms belonging to all R groups and the assumptions for the V_i^* s and U_i^* s are the same for the V_i s and the U_i s, respectively. The parameters of a given frontier for a group are estimated using data from firms in that group while the combined information from firms in all groups is used in estimating the parameters of the metafrontier model.

2.13 Farm Specific Factors

Some socio-economic and other exogenous variables have been identified by quite a number of authors to affect technical efficiency levels of farms. Some factors may be significant while others may not, depending on the type of study. A few of these factors include gender, age, farmers' educational level, experience and farm size. Others include access to credit, household size, extension contacts and distance from farmers' residence to the farm and nearest accessible road (Onumah et al., 2010, Mariano et al. 2010, Onumah and Acquah, 2010)

Previous studies have shown that, formal education, membership of an association, access to credit and extension contacts have a negative influence on inefficiency. Therefore, improvements in these variables will improve the efficiency of producers in order to increase their production performance. It has been observed that female farmers are more technically inefficient than their male counterparts (Nyakaga *et al.*, 2010, Nkamleu *et al.* 2010, Onumah and Acquah, 2010). Older farmers tend to be more inefficient since the influence of age on inefficiency is usually positive. Onumah and Acquah, (2010) observed that the size of a farm imposes an increasing effect on inefficiency and attributed this to management problems associated with over-sized farms.

2.14 Constraint Methodologies

The two main approaches usually employed in identifying and analysing constraints or limitations faced by farmers are the Kendall's Coefficient of Concordance and Garrett Ranking Technique. The Kendall's approach is easy and involves identifying constraints and presenting to farmers to rank from the most pressing to the least pressing constraints. The estimation is done such that the most pressing constraint ends up with the least mean

score estimate whereas the least pressing constraints record the maximum mean score. The Kendall's Coefficient of Concordance (W) shows the measure of agreement among several respondents who are assessing a given set of objects (Legendre, 2005).

The index, (W) also measures the ratio of the observed variance of the sum of ranks to the maximum possible variance of the ranks. W is said to exist within the range of 0 to 1 and must always be a non-negative (≥ 0) estimate. It assumes an estimate of 1 when ranks given by every judge is same that is a perfect agreement on constraints among judges or rankers. It takes 0 for maximum disagreement among rankers.

The estimation of the Coefficient of Concordance (W) is specified as:

$$W = \frac{12 \left[\sum G^2 - (\sum G)^2 / i \right]}{ib^2(i^2 - 1)} \quad (2.26)$$

where; G = addition of positions for every limitation; b = total sum of rankers; i = the number of ranked limitations.

The index estimated is tested for significance using the Chi-Square distribution of F-Statistic distribution. Based on this, the hypothesis formulated will be either rejected or not rejected. This form of hypothesis is stated as;

H_o : There is no consensus among the rankings of the limitations by the farmers

H_A : There is a consensus among the rankings of the limitations by the farmers.

Where H_o and H_A denote null and alternate hypotheses respectively.

2.15 Empirical Results of Previous Technical Efficiency Studies

The significance of efficiency as a method for improving output levels has influenced a considerable number of studies in this field.

A study conducted by Asante *et al.*, (2013) who used Cobb-Douglas production function model for the analysis found land, labour, fertilizer and pesticides to be significant in his study. Labour, fertilizer and pesticides had a negative relationship with output. He also recorded a mean technical efficiency of 78%, which implies that farmers in the area are below the potential output by 22%. Hence, there is a 22% possibility of increasing the output in the region by adopting the practices being employed by the best farms. The maximum and minimum efficiencies estimated were 95% and 40%.

The empirical application of the study is consistent with the models developed by Aigner, *et al.* (1977) and Meeusen and Ven den Broeck (1977); Battese and Tessema (1993). Hasnah *et al.* (2004) investigated technical efficiency for a sample of 80 smallholder oil palm producers in West Sumatra, over two years, 1999 and 2000. The maximum Likelihood method was used to estimate the stochastic frontier function. Output elasticities of the variables in the stochastic frontier production were 0.39, 0.13 and 0.35 for Total Weighted Trees (TWT), fertilizers, and labour respectively. The mean Technical Efficiency was estimated to be 0.66, which indicates that there is abundant room for increasing output through better extension work using informal education and selection of more suitable progressive producers without the need for producers to use more inputs.

Onumah *et al.* (2010) undertook a study on technical efficiency of fish farms in Ghana and used the Ox version 3.40 (Windows) package to obtain the Maximum Likelihood estimate for the translog stochastic production frontier. The study showed that the expected

elasticities for all inputs were significantly positive, meaning that all inputs have positive influence on fish farming. The inefficiency model revealed that the coefficients of experience was estimated to be significantly positive, indicating that older and more experienced fish producers are less technically efficient in their production than possibly new producers who are motivated, progressive and willing to implement new production system.

Seyoum, Battese and Fleming (1998) studied the technical efficiencies of two groups of maize farmers in Ethiopia. The Cobb-Douglas stochastic production function was used in measuring the technical efficiencies of the farmers. A cross-sectional data from 1995-1996 was used and fitted onto the stochastic frontier. Results from the study indicated that the project farmers had higher technical efficiencies and productivity compared to their non-project counter parts. Average technical efficiency for the project farmers was found to be higher than their non-project farmers. Their average efficiencies were estimated as 97% and 79% respectively. The study however suggested the adoption of new and improved farming technologies for maize farmers to increase their productivity and incomes.

Naceur *et al.* (2009) studied the efficiency of banks Jordan, Egypt, Tunisia and Morocco using DEA and employed a Metafrontier model to estimate the efficiency scores in a cross country setting. The study showed that regardless of the similarities in financial reforms, carried out in the four countries, the observed efficiency levels of banks vary significantly across these markets. It was found that the technology difference seemed to be an important factor in explaining the difference in efficiency levels.

Gul *et al.*, (2009) used DEA to estimate the efficiency of cotton farmers in Turkey. The objective was to identify and explain variations in technical efficiency of cotton farms and

determine the sources of inefficiency. Results from the research showed that the technical efficiency was 0.79 which proved that there are some opportunities to improving efficiency in resource use. Some sources of inefficiency identified included inefficient combination of inputs and inappropriate scales of production. The study revealed that older farmers were less efficient in production but also showed that technical efficiency increases with an increase in the years of experience in cotton farming.

Barnes and Revoredo-Giha (2011) employed a regional method to estimate the technical efficiencies of dairy farms. The stochastic frontier model was applied to establish six provincial frontiers and a pooled dataset to compare the efficiency of dairy farms in Eastern England, Western England, Northern England, Wales, Scotland and Northern Ireland. This study revealed that these regions were all operating under different frontiers thus had different efficiency levels.

Nkamleu, Nyemeck and Sanogo, (2006) employed DEA in their study of the Technology Gap and Productivity Difference in African Agriculture. The meta-frontier approach was used to study contrasts in effectiveness and technology gap crosswise over various areas of the continent. The outcomes demonstrated that technology gap has a vital impact in clarifying the capacity of agrarian areas in a single part to contend with other parts in various territories in Africa. The investigation has likewise demonstrated that normal technical efficiency score of the agricultural sector has been relatively steady after some time; while a negligible reduction of the profitability potential over the 30 years' term was found. The study also showed a huge profitability potential proportion gaps between districts of the landmass, going in the vicinity of 0.59 and 0.99. These qualities can be

translated as the technological gap confronted by the agricultural sector in those districts when their outputs are contrasted and the mainland level.

Donnet *et al.*, (2017) conducted a study on rain-fed maize production in Mexico using the meta-frontier approach to measure the technical efficiency and the environmental technology gap. The results obtained show the technical efficiency range from 70 to 100%, which indicates the gains that can be accrued by virtue of improved management of the current inputs and practices, and a range of the environment–technology gap between 32 and 82%, which indicates the limitations of the production environment which would require innovations in technologies and policies particularly adapted for the dry, the tropical and the more traditional regions.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This section of the study presents the conceptual and theoretical framework that underpin this study. Specified empirical models used in the study are highlighted; the data and its sources, various data collection techniques including the study areas are discussed in this section. The variables of interest included in the empirical models are also discussed; measurement methods of these variables, methods of analyzing each objective and their relevant hypotheses tests are all presented in this chapter.

3.1.1 Conceptual Framework

The approach adopted for this study is the parametric frontier approach to technical efficiency estimation. Specifically, the stochastic frontier analysis established by Aigner et al. (1977) is adopted for the study. An improvement of the methodology of the stochastic frontier model, precisely the stochastic meta-frontier model which was developed by Battese and Roa (2002) and BATESSE et al. (2004) with reference to Hayami (1969) and Ruttan's (1971) theory of meta-production technology is also adopted to remedy the differences in technology that could be improperly classified as technical inefficiency in maize production.

The concept of this research is based on the presumption that outputs of maize in the three different environment types selected for this study are influenced by three main factors. These factors generally include the average output which is generated from the specified

set of input resources, the ecological zone in which production is undertaken and the technical inefficiency of the production agent. Figure 3.1 gives an illustration of this concept.

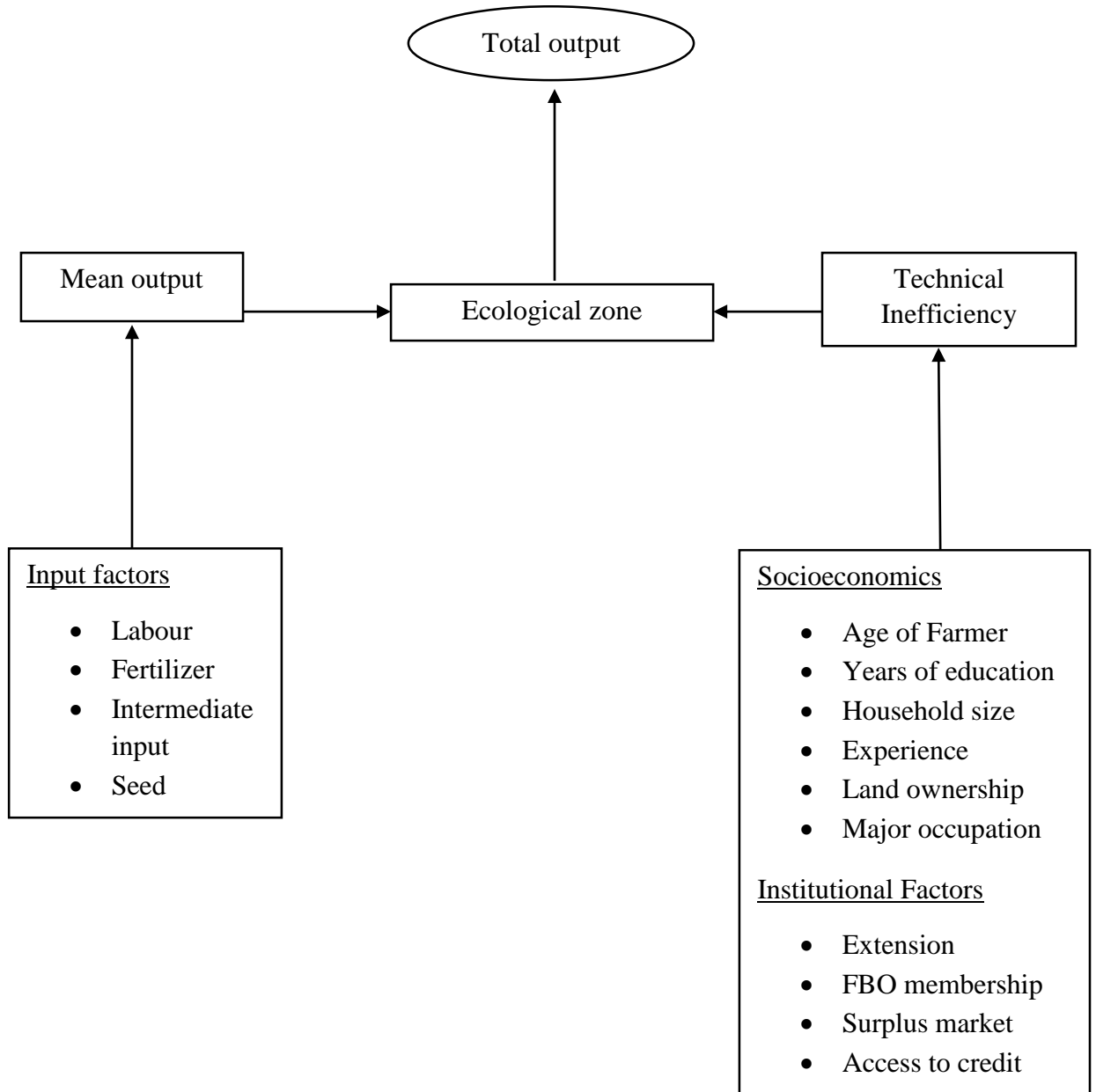


Figure 3.1 Conceptual Framework

Source: Authors own construct

3.2 Theoretical Framework

3.2.1 Stochastic frontier model

The standard stochastic frontier model takes into account the breakdown of the error term into arbitrary error and inefficiency effects to avoid referring to all forms of errors as being random.

The model for a cross section data is written as:

$$Q_i = f(X_i; \beta) \cdot \exp(v_i - u_i) \quad (3.1)$$

where: Q_i represents the output of maize by the i^{th} farm; X_i is the vector of input quantities of the i^{th} farm; β is the vector of unknown parameters to be estimated; v_i accounts for random effects that are beyond the influence of the producing agent and u_i is a positive error component that measures the impact of technical inefficiency that falls under the producers influence.

The stochastic frontier production model splits the error term into two different components, one associated with technical efficiency and the second associated with the exogenous random effects. The error component v_i is presumed to be freely and identically distributed with a zero mean and a sustained variance $\{iid\ N(0, \sigma_v^2)\}$. The error component u_i is also presumed to be distributed as a normal distribution truncation with a mean of μ_i and a variance σ_u^2 $\{\mu_i \sim N(\mu_i, \sigma_u^2)\}$. Thus the error term associated with inefficiency is clarified by external factors indicated as $\mu_i = Z_i \delta$ (Mariano *et al.*, 2010). Specifying the error components in this form implies that the production process is

influenced by a non-positive component which makes the actual production lie either on or below the production possibility frontier of the farm. The Z_i is a 1 x n vector of exogenous variables which define inefficiency and δ is an n x 1 set of unknown coefficients that are yet to be computed. The existence of unexpected disturbance in the form of weather fluctuations, measurement errors and other disturbances beyond the producers control makes the frontier variable by generating inefficiencies.

The maximum likelihood estimate for the frontier gives the estimate of β and γ . Where γ , is the total variation in the actual yield form the frontier yield. It is given as the proportion of the difference of the error corresponding to the inefficiency (σ_u^2) to the general differences within the model. The total variation within the model is given as the aggregate of the differences of the error related with the inefficiency (σ_u^2) and the sum of the error associated with the random factors (σ_v^2).

The gamma (γ) estimate is shown as:

$$\gamma = \frac{\sigma_u^2}{\sigma^2} \tag{3.2}$$

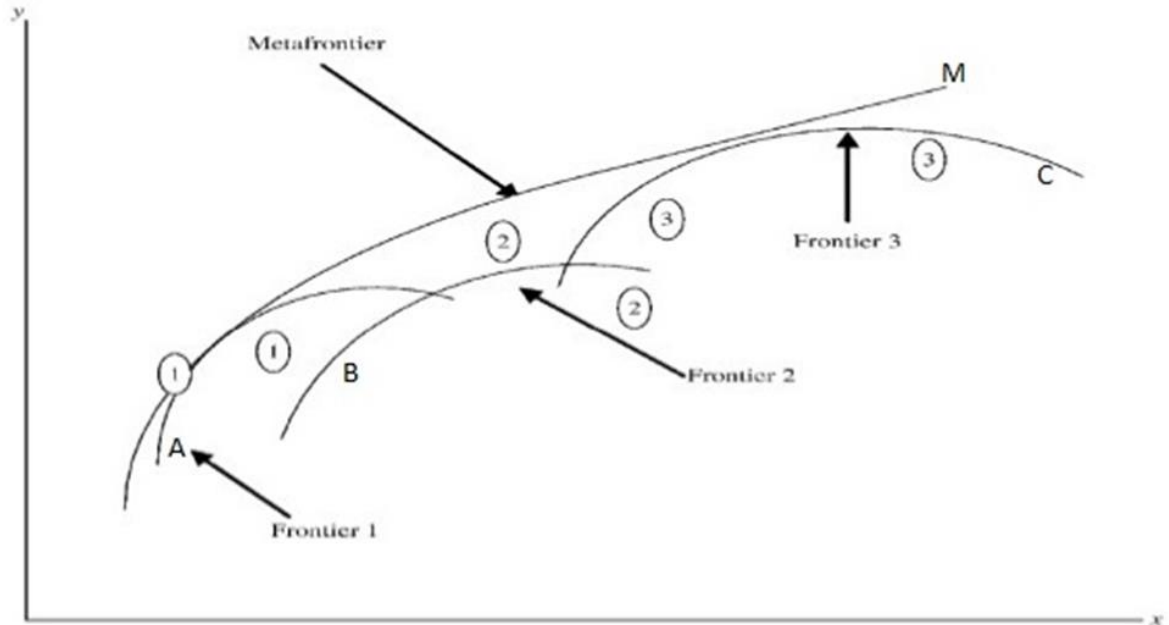
where, $0 \leq \gamma \leq 1$. This means that the closer the value of the gamma is to 1, the more the movement away from the frontier by the actual yield is due to inefficiency factors under the farmers' control. If the gamma value is closer to 0, the extent to which the observed output sways away from the frontier is more associated to exogenous random factors beyond the producer's control. In the case where the value of gamma lies in-between 0 and 1, the deviation from the frontier may be attributed to both inefficient and random factors.

The relationship between the inputs and outputs is specified in a functional form which bears properties which include flexibility, linearity in parameters, regularity and parsimony according to (Coelli *et al.*, 2005). The functional form which satisfies the previously stated properties is the transcendental logarithmic (translog) functional form developed by Christensen *et al.*, (1973) as cited in Mariano *et al.*, (2010) is used in this study for the econometric estimation of the production function.

The translog function is specified as:

$$\ln Q_i = \ln \beta_o + \sum_{j=1}^n \beta_j \ln X_{ji} + \frac{1}{2} \sum_{j=1}^n \sum_{k=1}^n \beta_{jk} \ln X_{ji} \ln X_{ki} + (v_i - u_i) \quad (3.3)$$

where $\beta_{jk} = \beta_{kj}$ to satisfy the concavity property of the transcendental logarithmic function. The equation above is estimated parametrically with the MLE procedure with the assumption that the error terms have a truncated-normal distribution.



Source: Adapted from Battese et al. (2004).

Figure 3.1 Metafrontier illustration

The curve labeled M represents the deterministic frontier output of maize which is regarded to have zero inefficiency effects. Observations of output that lie below the deterministic frontier are considered to be inefficient due to the random noise associated with production functions. Some examples of these random factors that generate inefficiencies include unfavorable weather conditions, pests and diseases, social or institutional shocks, economic shocks, uncertainties as well as measurement and aggregation errors. Based on the nature and effects of the random factors mentioned above, some frontiers may be closer or further away from the Metafrontier curve labeled (M).

In this study, three distinct frontiers are estimated for maize production in three different ecological zones across the country to determine the efficiency level of each region or

within each ecological zone relative to their production technology illustrated by their group frontier. It will be inaccurate to conclude that maize producers using a particular production technology in a different ecological zone are more efficient than other producers using different technologies in another ecological zone based on the individual production frontiers. A meta-frontier model which envelopes the three frontiers across the three ecological zones allows for us to draw the conclusion of which group of producers are more efficient. Figure 3.1 provides a conceptual illustration of a meta-frontier production function. The technology gap is measured by the distance between the individual frontiers (the different ecological zones) and the Metafrontier which represents the best technology available in the maize industry.

3.2.2 Stochastic Metafrontier Approach

The stochastic Meta-Frontier Analysis involves the envelopment of the stochastic frontiers of different groups within the same industry (maize producers across the three ecological zones in Ghana). The concept of the meta-production function has its bases hinged to the hypothesis that every producer within the different groups or ecological zones could have access to the same technology but only circumstances such as natural resource endowments, the economic environment and relative prices of inputs etc. influence the decision to work on different sections of the frontier (Lau and Yotopoulos, 1989). The modified version of this approach by Battese and Rao (2002) is employed for this study. If the stochastic frontier specified in model 3.1 for the separate ecological zones is assumed for the data set, then our stochastic meta-frontier model can equally be specified as:

$$Q_i^* = f(X_i; \beta^*) \cdot \exp(v_i^* - u_i^*) \quad (3.4)$$

where Q_i^* is the meta-frontier output and β^* the coefficient set.

The meta-frontier model specified above is such that its output is greater than the outputs of the individual stochastic frontiers of the different ecological zones.

This is represented as:

$$f(X_i; \beta^*) > f(X_{ji}; \beta_j) \quad (3.5)$$

where $f(X_i; \beta^*)$ represents the output function of the meta-frontier while $f(X_{ji}; \beta_j)$ represents the output function of the stochastic frontiers of any of the three ecological zones.

According to Battese and Rao (2002), the observed output of an i^{th} farm may be written in terms of the meta-frontier as:

$$Q_i = e^{-u_i} \cdot \frac{e^{x_i \beta}}{e^{x_i \beta^*}} \cdot e^{x_i \beta^* + v_i} \quad (3.6)$$

The deterministic meta-frontier output devoid of any inefficiency is expressed as:

$$Q_i^* = e^{x_i \beta^* + v_i} \quad (3.7)$$

The technical efficiency of the i^{th} firm within the j^{th} group relative to the stochastic meta-frontier is expressed as:

$$TE^* = \frac{Q_i}{Q_i^*} = \frac{e^{-u_i} \cdot \frac{e^{x_i \beta}}{e^{x_i \beta^*}} \cdot e^{x_i \beta^* + v_i}}{e^{x_i \beta^* + v_i}} = e^{-u_i} \cdot \frac{e^{x_i \beta}}{e^{x_i \beta^*}} \quad (3.8)$$

The term $\frac{e^{x_i\beta}}{e^{x_i\beta^*}}$ is what we call the Technology Gap Ratio (TGR). The term e^{-u_i} is the measure of technical efficiency of the individual stochastic frontier model. The Technology Gap Ratio (TGR) is defined as the ratio of the output for the production frontier of the j^{th} group (any of the ecological zones) in respect to the potential yield characterized by the meta-frontier function, given the available inputs.

This is expressed as:

$$TGR = \frac{e^{x_i\beta}}{e^{x_i\beta^*}} \quad (3.9)$$

The Environmental-Technological Gap Ratio (ETGR)

The Technological Gap Ratio (TGR) articulation characterized above in equation (3.9) shows the distance that lies between the production frontier for a specific production unit in an industry and the metafrontier for the industry. Villano et al. (2006), asserted “that it is important to expand this definition to environmental-technology gap ratio (ETGR). This definition better clarifies the requirements put on the potential yield by nature, and the collaborations between the environment and the production innovation.” This is particularly critical for agrarian enterprises in which the capability of the production system is to a great extent reliant on the agroecosystem.

An alternative expression of technical efficiency relative to the meta-frontier can be derived from the above equations. This is given as:

$$TE^* = TE_i * TGR_i \quad (3.10)$$

(Battese *et al.*, 2004)

This expression means that, the technical efficiency ratio of the farm relative to the meta-frontier is a product of the technical efficiency of the stochastic frontier of a given ecological zone and its own technology gap ratio. This method of computing for technical efficiency corrects for the technical efficiency estimates of production units that may be using different types of production technology in order to be able to compare them by directing our attention to the space that separates the group frontiers for the overlying-frontier.

After obtaining the value of the computed estimates for the meta-frontier that envelopes the components of the estimated stochastic frontiers for the different ecological zones, a special criterion is used to identify the best envelope. Two separate criteria are described by Battese and Roa (2002). The first criterion involves the summation of total displacements away from the meta-frontier yield by the output of each single stochastic production frontier involved. The other paradigm depends on the addition of squares of departures from the meta-frontier estimates from each independent frontier. The best way to decipher the two procedures is by utilizing a linear programming approach. In this research, we minimize the sum of absolute deviations according to the procedure adopted from Binam *et al.*, (2008). The linear programming problem below is then solved after computing for the estimates of the frontiers of each ecological zone (β_j) and the frontier of the meta-production function (β^*).

Minimize,

$$L = \sum_{i=1}^n |\ln f(X_i; \beta^*) - \ln f(X_{ji}; \beta_j)|$$

Subject to:

$$\ln f(X_i; \beta^*) \geq \ln f(X_{ji}; \beta_j) \quad (3.11)$$

The departures speak to the radial separation between the meta-frontier and the j^{th} ecological zone (the individual frontiers for the three ecological zones) evaluated at their observed input vector.

3.3 Model Specification

The translog function has been established by many studies such as Onumah *et al.*, (2010) and Baten *et al.*, (2009) to be effective for the estimation of efficiency in production methods. This functional form is relatively flexible and avoids constrained presumptions of having the elasticity of production set to be constant nor elasticity of substitution among inputs. The empirical model determined for this investigation is as per the following:

$$\ln Q_i = \ln \beta_o + \sum_{i=1}^4 \beta_i \ln X_i + \frac{1}{2} \sum_{i=1}^4 \sum_{j=1}^4 \beta_{ij} \ln X_i \ln X_j + (v_i - u_i) \quad (3.12)$$

Where:

Q_i = Output (kilograms/ ha)

X_1 = Labour (Man-days/ha)

X_2 = Fertilizer (kilograms/ha)

X_3 = Intermediate input (kilograms/ha)

$X_4 = \text{Seed (Kilograms/ha)}$

The meta-frontier model is also specified as:

$$\ln Q_i^* = \ln \beta_o^* + \sum_{i=1}^4 \beta_i^* \ln X_i + \frac{1}{2} \sum_{i=1}^4 \sum_{j=1}^4 \beta_{ij}^* \ln X_i \ln X_j + (v_i^* - u_i^*) \quad (3.13)$$

Where the input variables defined in the above model for the meta-frontier are equal for those characterized for the stochastic model of the three ecological zones. From the above models (3.12) and (3.13), the technical efficiencies and productivity are estimated.

3.4 Estimating Productivity

The fractional versatility of generation concerning the individual sources of input is estimated with the aid of the translog production frontier model in order to quantify the efficiency levels of each zone. The estimated coefficients of the translog production function are not to be explicitly explained as elasticity of yield regarding the various input variables as in the case of a Cobb-Douglas functional form. For this reason, the output and input variables are standardized by their personal averages, so that the coefficients of the first order can be explained as the elasticity of output in relation to the various input variables. In this study, the elasticities are computed by rescaling the variables to have unit means which mean that the coefficient of the squared term (β_{jj}) and cross product terms (β_{jk}) turns to zero and the first term (β_j) is interpreted as direct elasticities.

The expression below illustrates the general specification for the elasticity of output with respect to a variable in

$$\varepsilon_q = \frac{\partial \ln E(Q_i)}{\partial \ln X_{ji}} = \left\{ \beta_j + \beta_{jj} \ln X_{ji} + \sum_{i=1}^n \beta_{jk} \ln X_{ki} \right\} = \beta_j \quad (3.14)$$

$E(Q_i)$ represents the elasticity of output, the X's represent the input variables and the β 's are the coefficients to be estimated. The subscripts k and j represent the input variables k and j respectively.

3.5 Returns to scale

The total of all elasticities of yield regarding the various input resources represents the computed returns to scale coefficient. This is expressed as:

$$RTS = \sum \varepsilon_{qi} \quad (3.15)$$

If the value of $\varepsilon > 1$ then it is assumed to be an increasing returns to scale. This means that, if all inputs are increased by one percent, the proportionate increase in output will be more than one percent; if $\varepsilon < 1$, then it implies a decreasing returns to scale which means that a proportionate increase in all the input variables results in a less than proportionate increase in the observed output. Finally when $\varepsilon = 1$, the production unit or maize farm in accordance to this study is said to be experiencing a constant returns to scale.

3.6 Empirical Estimation of Technical Efficiency

The technical efficiency estimation is expressed as:

$$Q_i^* = f(X_i; \beta) \cdot \exp(v_i)$$

$$TE = \frac{f(X_i; \beta) \cdot \exp(v_i - u_i)}{f(X_i; \beta) \cdot \exp(v_i)} = \exp(-u_i) \quad (3.16)$$

The value of the technical efficiency in the stochastic model is given by the value derived from the above model. However the technical efficiency measure of the various ecological zones relative to the meta-frontier TE^* is defined by the product of the technical efficiency (TE) of the individual stochastic frontier in model (3.16) and the value of the TGR in model (3.9). The meta-frontier output Q_i^* can then be obtained after obtaining the TE estimate in model (3.9) since the observed output is computed from the data.

The range of the technical efficiency values lies within the range of zero and one ($0 \leq TE^* \leq 1$). The nearer the estimated figure of the TE is to 1, the higher the efficiency of the producer and consequently the further away the TE value is from 1, the more inefficient the producer is. A technical efficiency score of 1 means the producer is fully efficient. Any divergence from 1 means the producer is technically inefficient and has a technology gap to close relative to the meta-frontier. The environmental-technology gap ratio (ETGR) explains the ability of individual farms in different ecological zones within the country to compete with each other. The estimates of technical efficiency are computed by amplifying a maximum probability work for the frontier model given below as:

$$\ln(L) = -\frac{N}{2} \left(\ln \left(\frac{\pi}{2} \right) + \ln \sigma^2 \right) + \sum_{j=1}^n \ln \left[1 - \Phi \left(\frac{\varepsilon_j \sqrt{\gamma}}{\sigma \sqrt{(1-\gamma)}} \right) \right] - \frac{1}{2\sigma^2} \sum_{j=1}^n \varepsilon_j^2 \quad (3.17)$$

The $\Phi(\bullet)$ is a standard density function, ε is the output functions residual, σ and γ assume their previously defined parameters.

3.7 Description of variables used in the frontier model

Output: this is the sum of both major and minor season output of maize in the 2017 production year. It is measured in kilograms/ha.

Land size: the most basic input for agricultural production is land. Land size as an input variable is very important in efficiency studies. In this study land size represents the total land area used for maize production by each farmer and this is measured in hectares. The size of land influences output positively, holding all things constant.

Labour: this input variable is composed of both family and hired labour and was measured in man-days. Family and hired labour were both assumed to be equally productive and are summed up and measured in man-days/ha. Man-days is computed using the rule that one adult male equals 1 man-day; one adult female equals 0.75 man-days and one child equals 0.5 man-days all working for one day (8 hours). These assumptions are based on similar studies done by Battese *et al.*, (1996), Onumah *et al.*, (2010) and Onumah *et al.*, (2013).

Fertilizer: this informs the quantity of fertilizer required during the production season for plant growth and is measured in kilograms/ha. This group includes all the various types of fertilizer; nitrogen, phosphorus and potassium (NPK); nitrogen fertilizer (urea); diammonium phosphate (DAP) (Njeru, 2010).

All input and output variables are normalized by the total cropped land area in each ecological zone. The reason for this is to control for the differences in land area under production. This is a specification adopted from Onumah and Acquah (2010).

Intermediate input: this is the quantity of weedicides, pesticides and all other forms of agrochemicals employed by farmers during their production process over the production

season in the study areas. It was measured by summing up all the agrochemicals used and measured in kilograms per hectare.

Seed: this represents the major primary input which is the planting material used for the production process. It was measured in kilograms per hectare.

Table 3.1 Variables in Frontier Models

Variable	Measurement	Apriori Expectation
Output (Dependent)	Kilograms/ha	
Input Variables		
Labour (X_1)	Man-days/ha	+ve
Fertilizer (X_2)	Kilograms/ha	+ve
Intermediate input (X_3)	Kilograms/ha	+ve
Seed (X_4)	Kilograms/ha	+ve

3.8 Empirical Model for the Determinants of Technical Inefficiency

The model below specifies the determinants of inefficiency as:

$$\mu_i = \delta_o + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} \quad (3.18)$$

The variable μ_i is a positive error component. It denotes the impact of technical inefficiency relative to the stochastic production frontier. This term is explained with basic attributes of the decision making unit and other elements beyond the producers control.

This model generates variance parameters that are specified as:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad (3.19)$$

From the above relation, a variance parameter ratio which relates the variability of the u to the total variability in u and v can also be expressed as:

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \quad (3.20)$$

Where the range of the gamma lies between zero and one, $0 \leq \gamma \leq 1$. This means that the closer the value of the gamma is to 1, the more the deviation from the observed output from the frontier is due to inefficient factors within the farmers' control. If the gamma value is closer to 0, the deviation of the observed yield away from its highest potential is as a result of exogenous random causes beyond the producer's influence.

If the coefficient of a variable within the inefficiency model possesses a negative sign, it implies that the variable in question reduces the inefficiency of the farmer. On the other hand, if the coefficient of a variable that is part of the inefficiency model is positive, it means the variable in question adds to the inefficiency of the farmer and makes the producer less efficient. The inefficiency effects are estimated simultaneously with the frontier model by a single stage maximum likelihood procedure.

3.9 Description and Measurement of factors that constitute the Inefficiency Model

Gender: this variable is specified as a dummy variable where a male farmer assumes a value of 1 and a female farmer assumes a value of 0. Various researchers have had different signs for this variable depending on the crop type being studied so that reason the expected

sign for this variable is intermediate. Binam et al (2008) in his study on cocoa farmers found obtained a negative sign which implied that male farmers reduced inefficiency.

Educational Level: this variable informs on whether the farmer has received any form of formal education. It is measured as the level of education the farmer has attained. Basic education which includes primary and JHS is recorded as level 1; Level 2 represents secondary education which includes SHS, vocational and technical training; Level 3 represents tertiary education. Educational level is seen as an enhancer of efficiency and productivity. The reason being that, the higher the educational level of the producer, the easier it is to use input in their right proportions and to also apply new and improved methods in their production process.

Age of farmer: this variable is measured in year. It is presumed that the younger a farmer is, the more active they will be in their production process but the age of a farmer can influence their level of experience which may give older farmers an edge over younger ones in terms of efficient allocation of inputs to maximize output. For this reason, the sign remains intermediate.

Experience: this variable represents the number of years a farmer has actively engaged himself in maize production and is measured in years. All things being equal, as a farmer's experience in maize production increases over the years, his technical efficiency as a farmer is expected to increase.

FBO membership: this variable indicates whether belongs to a farmer based organization and is captured as a dummy variable. A farmer is designated by a value of 1 if he belongs

to an FBO and a value of 0 is assigned to a farmer that doesn't belong to an FBO. The sign is expected to be positive.

Extension Contact: this factor is included because of the important part Agricultural Extension Agents play in disseminating new and improved farming technologies. They relay new information between researchers and farmers so the more contact farmers have with the extension agents, the more their ability to improve upon productivity and efficiency. Nyakaga et al (2010) and Binam et al (2008) both observed that increased extension contacts reduced inefficiency among farmers. The variable is measured as the number of visits a farmer receives from Agricultural Extension Agents within the production year.

Market: this variable indicates whether a farmer has ready market for the maize output after harvest. It is measured as a dummy where a farmer with a ready market takes a value of 1 and a farmer without a ready market takes a value of 0. A farmer's assurance of a ready market motivates adequate investment into the production process to obtain maximum benefits.

Access to credit: this variable shows whether a farmer receives any support in the form of cash credit to finance his or her farm operations. Availability and access to credit is an important asset to a farmer's production process because they must incur cost to acquire the various inputs for the production process. It is assumed that farmers' access to credit reduces the constraint of input acquisition in order to increase efficiency and productivity. It is measured as a dummy where farmers who are able to obtain credit are assigned a value of 1 or otherwise 0.

Table 3.2: Inefficiency variables and their a priori expectations

Variable	Description	Apriori sign
Z_1	Age of farmer	-ve/+ve
Z_2	Educational level of farmer	-ve
Z_3	Household size	-ve
Z_4	Experience	-ve
Z_5	FBO member	-ve
Z_6	Extension contact	-ve
Z_7	Land ownership	-ve
Z_8	Major occupation	-ve
Z_9	Surplus market	-ve
Z_{10}	Access to credit	-ve

3.10 Statement of Hypothesis

The following hypothesis tests are performed for this research analysis based on the assumptions of the model.

- a. $H_o : \beta_{ij} = 0$. This is the null hypothesis that the Cobb-Douglas functional form is the valid model appropriate for the datasets and it sufficiently represents the production frontier functions. It is tested against the alternative $H_1 : \beta_{ij} \neq 0$.

- b. $H_o : \gamma = \delta_0 = \delta_1 = \delta_2 =, \dots = \delta_9 = 0$. This means the inefficiency factors are nonexistent within the expression at each given level and each farmer operates on the production frontier against the alternative that $H_1 : \gamma \neq \delta_0 \neq \delta_1 \neq \delta_2 \neq, \dots \neq \delta_9 \neq 0$.
- c. $H_o : \gamma = 0$: this hypothesis suggests that the inefficiency terms are non-stochastic. This means that, the stochastic frontier model turns into a conventional average response function (OLS) where the explanatory variables of the inefficiency model are incorporated into the production function. The alternative hypothesis against which it is tested is $H_1 : \gamma \neq 0$.
- d. $H_o : \delta_0 = \delta_1 = \delta_2 =, \dots = \delta_9 = 0$. This hypothesis suggests that the simpler half normal distribution is an adequate representation of the data given the general truncated normal distribution that is assumed. The alternative hypothesis is specified as $H_1 : \delta_0 \neq \delta_1 \neq \delta_2 \neq, \dots \neq \delta_9 \neq 0$
- e. $H_o : \delta_1 = \delta_2 =, \dots = \delta_9 = 0$. This hypothesizes that the factors incorporated into the technical inefficiency model have no effect on the level of efficiency. Thus farm specific factors do not influence inefficiencies. The alternative hypothesis is specified as $H_1 : \delta_1 \neq \delta_2 \neq, \dots \neq \delta_9 \neq 0$.
- f. $H_o : f(X; \beta^{IV}) = f(X; \beta^{LV})$. This proposes that there is no difference in maize outputs in the different ecological zones, thus the meta-frontier specification is not required. The alternative hypothesis is however given as $H_1 : f(X; \beta^{IV}) \neq f(X; \beta^{LV})$

3.10.1 Statistical testing technique for the hypothesis

The Generalized Likelihood ratio test is employed to approve these hypotheses and is indicated as:

$$LR(\lambda) = -2[\{\ln L(H_0)\} - \{\ln L(H_1)\}] \quad (3.21)$$

$L(H_0)$ and $L(H_1)$ represent the estimations of the likelihood functions got from the constrained and unconstrained models (null and alternative hypothesis) individually. These have a chi-square appropriation with degrees of flexibility equivalent to the contrast that lies between the number of computed coefficients under the H_1 (unconstrained model) and H_0 (constrained model). The mixed chi-square distribution is employed where the test includes a γ . When the designated critical value is higher than the assessed chi-square value, the H_0 is accepted. The likelihood functions value for the unconstrained representation including the test which checks the appropriateness of the utilization of the meta-frontier is the summation of the likelihood value for all the different ecological zones. The likelihood function of the of the constrained model is the log likelihood estimation of the combined stochastic frontiers of the three regions. The degree of freedom is attained by finding the distinction that lies between the quantity of parameters computed for the unconstrained model and that of the constrained model.

3.11 Analytical Software

The OX metrics programme developed by Brummer (2015) was used for the estimations in this analysis.

3.12 Study Area

The Ghanaian landmass is partitioned into six natural ecological zones and these include the Coastal Savannah, Guinea Savannah, Sudan Savannah, Forest Savannah Transition, High Rainforest and the Semi-Deciduous Rainforest. The entire of Northern and Upper West regions of the country are covered by the Guinea Savannah. It likewise involves certain segments of Upper East region and the topmost bits of the Volta and Bono-Ahafo areas. This ecological area has one precipitation period that ranges from May to October. Yearly precipitation is around 1000 mm in this natural zone. The Sudan Savannah lies at the eastern part of the top section of the Upper Eastern region which has a yearly precipitation of around 500 – 700 mm.

The Transition zone exists in the center area of the Bono-Ahafo region, the top piece of both Eastern and Ashanti regions and the western parts of the Volta landmass. This particular geographical space has a two seasonal precipitations and a yearly precipitation of around 1200 mm. The Semi-Deciduous zone lies over the northern piece of Western area through southern portions of the Bono-Ahafo, Eastern and Ashanti regions. It additionally involves the eastern parts of Volta area and an expansive segment of the Central region. It likewise has two precipitation seasons with yearly precipitation achieving 1400mm. A huge chunk of the Western region lies in the High Rainfall zone. A little piece of Central locale additionally falls within this zone. Yearly precipitation is more than 2000 mm. The Coastal Savannah covers the Central region all the way to the Greater Accra and to the Volta region with a single rainfall period with about 600 mm of annual rainfall.

This study will sample farmers from three different ecological zones in Ghana namely the Forest Zone, the Transition zone and the Savannah zone. The Guinea savannah which covers most of the northern part of Ghana is classified as the Savannah zone for the study while the Savannah-Forest transition zone which spans over most of the most of the Bono-Ahafo region and the upper part of the Eastern and Ashanti regions is selected as the transition zone in this study. The Semi-deciduous rain forest within the Eastern region is selected to represent the Forest zone in this study. Figure 3.3 shows a demarcation of the Ghana map according to the various ecological zones.

3.13 Data type, Sampling and Data Collection Methods

The study was dependent on primary data from maize farmers across three different ecological zones in Ghana. The data collected for the study was both qualitative and quantitative in nature. The qualitative data collected included information on some socioeconomic factors of the respondents. The quantitative data also included some socio-demographic characteristics of the maize farmers, quantity and cost of inputs, the quantity and prices of outputs and other relevant quantitative variables required for the study.

A total sample size of 270 was taken but after data cleaning a total of 224 was deemed useful. 80 maize farmers were sampled from the savannah zone, 82 maize farmers from the transition zone and 62 maize farmers from the forest zone. The study employed the purposive sampling technique to select locations within the regions that fall in the required transition zones chosen for the study. The farmers were selected using the snowball sampling technique where the respondents directed us to other prospective respondents.

Data collection was done by interviewing farmers with the aid of a structured questionnaire. This procedure was carried out in all three ecological zones over a period of three weeks. The survey instrument was pretested to adhere to field conditions and inconsistencies corrected before dispensing. Irregularities were eliminated and other relevant information gathering questions required for analysis were included in the survey instrument. Enumerators were employed from the various study areas to remedy the potential language barrier. These enumerators were taken through the survey instrument to establish a general understanding of the objectives of the study, the kind and nature of responses required and the variables to be measured prior to the data collection process.

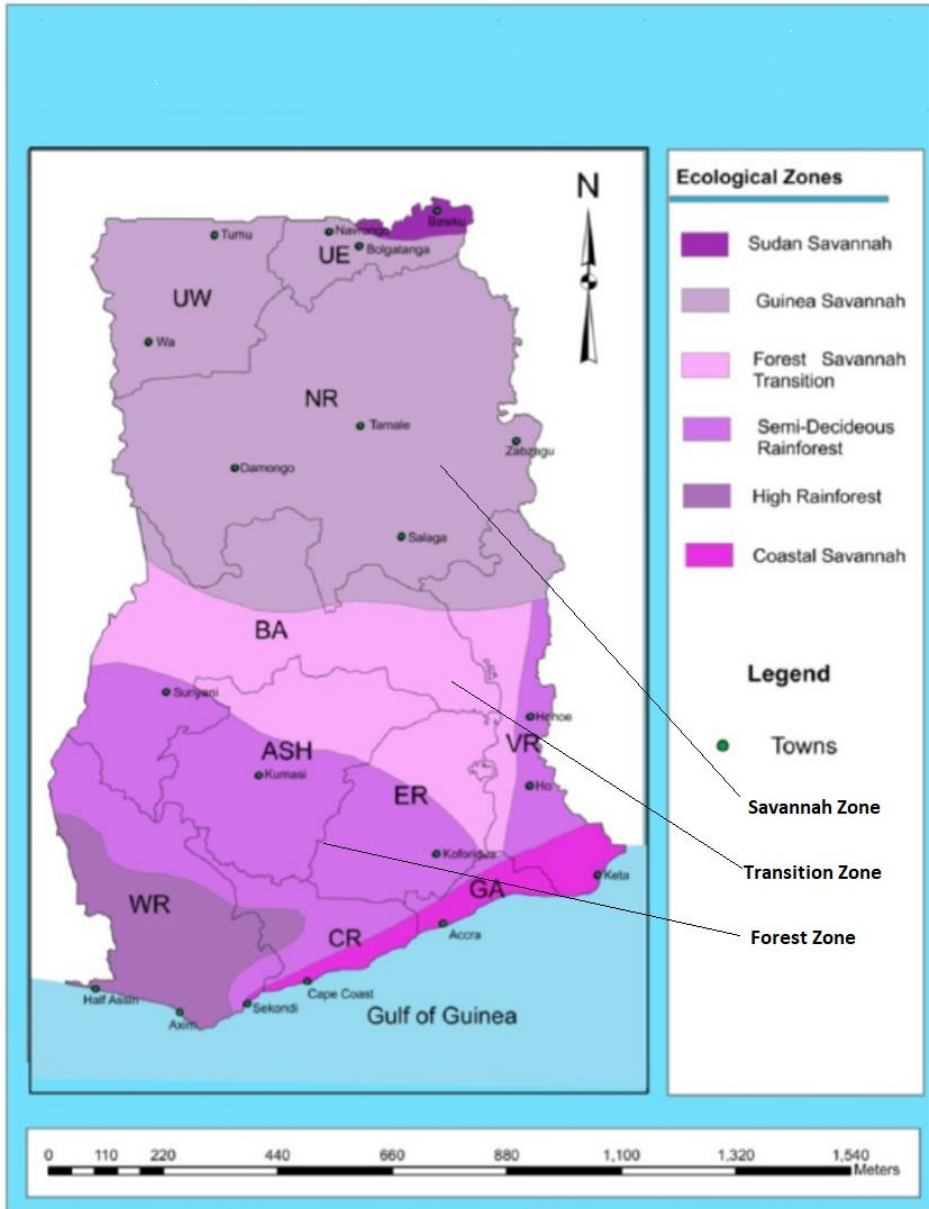


Figure 3.3 Ecological Zones in Ghana

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The chapter presents and discusses the results of this research. It provides an exhaustive account of the socio-economic characteristics of respondents from the various study areas, the productivity and relative technical efficiencies of maize producers within the three selected ecological zones (Savanna, Transition and Forest zones). Results of the determinants of technical inefficiency and environmental-technology gap ratios for the various ecological zones are also deliberated on. The chapter also brings to bare the results of the Metafrontier analysis and compares the technical efficiency estimates for producers of maize in the savanna, transition and forest zones.

4.2 Socioeconomic Characteristics of Farmers

4.2.1 Summary statistics of farmer-specific characteristics of maize farmers

The tabulation of the analysis presented in table 4.1 shows that the mean age of farmers interviewed in the three study areas is 44 years. The savanna zone had an average farmer age of 45 years with the transition zone recording an average of 46 years whereas the forest zone had an average of 48 years. This means that maize farmers in the three study areas are middle-aged which is consistent with a study by Kuwornu *et al.* (2013) that found the average age of maize farmers to be 44 years.

Table 4.1 Table of farmer-specific characteristics

Variable	Savanna zone	Transition Zone	Forest Zone	Pooled
Age (Years)				
Mean	39.86	45.56	47.65	44.10
Std. Dev	9.67	11.95	11.03	11.36
Minimum	26	28	23	23
Maximum	75	90	70	90
Education (Years)				
Mean	6.06	2.63	6.73	4.99
Std. Dev	5.93	4.41	5.17	5.49
Minimum	0	0	0	0
Maximum	17	14	19	19
Experience (Years)				
Mean	12.31	20.99	20.50	17.75
Std. Dev	10.08	12.56	11.14	11.99
Minimum	2	3	2	2
Maximum	45	59	47	59
HHS (Number)				
Mean	11.68	9.28	6.50	9.37
Std. Dev	7.37	4.71	2.70	5.79
Minimum	1	1	1	1
Maximum	40	30	14	40
Farm Distance (Km)				
Mean	7.28	5.71	3.65	5.70
Std. Dev	5.18	5.64	2.94	5.05
Minimum	2	0	0	0
Maximum	30	25	20	30

Source: Field Survey (2018)

According to table 4.1 the mean number of years that a farmer has had formal education in the savannah, transition and forest zones are approximately 6 years, 3 years and 7 years respectively. Table 4.2 shows that out of a total of 224 farmers interviewed, a total of 108 representing 48% of the sample had no formal education. 11 farmers out the total sample of farmers from the savanna zone had primary education with 10 of them having Junior high school (JHS) education, 12 having senior high school or vocational and technical (SHS/V&T) education and 13 having received tertiary. None of the respondents from the transition zone had any form of tertiary education. The table also shows that 14 farmers from the forest zone had received primary education with 21 farmers having at least JHS education. 6 farmers from the forest zone had received SHS/V&T education and 5 of them had tertiary education. A total of 18 farmers representing only 8% of the sample had received tertiary education. As specified by Al-Hassan (2008) farmers must have some level of formal education to understand and be able to utilize modern farming methods efficiently to achieve their frontier output.

The mean years of experience in maize farming for farmers in the savanna zone was 12 years and 21 years for both the transition and forest zones. The maximum years of experience observed for the savannah, transition and forest zones are 45, 59 and 47 years respectively and the observed minimum years of experience were 2, 3 and 2 years respectively. It is usually expected that a farmer with more years of experience in maize farming will be more efficient in production than a farmer with less years of experience. A study by Kuwornu *et al.* (2013) found the mean farm experience of maize farmers to be

20.09 years and postulated that farmers would have obtained better managerial skills necessary for agricultural production by this time.

Table 4.2 Socioeconomic characteristics of maize farmers by ecological zone

Variable	Savanna Zone N=80	Transition Zone N=82	Forest Zone N=62	Pooled N=224
Gender				
Male	78 (97.5)	79 (96.3)	45 (72.6)	202 (90.2)
Female	2 (2.5)	3 (3.7)	17 (27.4)	22 (9.8)
Marital Status				
Married	73 (91.3)	78 (95.1)	59 (95.2)	210 (93.8)
Otherwise	7 (8.8)	4 (4.9)	3 (4.8)	14 (6.2)
Educational Level				
None	34 (42.5)	58 (70.7)	16 (25.8)	108 (48.2)
Primary school	11 (13.8)	8 (9.8)	14 (22.6)	33 (14.7)
JHS	10 (12.5)	14 (17.1)	21 (33.9)	45 (20.1)
SHS/V&T	12 (15.0)	2 (2.4)	6 (9.7)	20 (8.9)
Tertiary	13 (16.3)	0 (0)	5 (8.1)	18 (8)
Major Occupation				
Maize farming	62 (77.5)	53 (64.6)	38 (61.3)	153 (68.3)
Otherwise	18 (22.5)	29 (35.4)	24 (38.7)	71 (31.7)
Land Ownership				
Purchase	1 (1.3)	2 (2.4)	7 (11.3)	10 (4.5)
Rent	5 (6.3)	52 (63.4)	20 (32.3)	77 (34.4)
Family land	65 (81.3)	9 (11.0)	11 (17.7)	85 (37.9)
Borrowed	9 (11.3)	19 (23.2)	25 (38.7)	52 (23.2)
FBO Membership				
Member	2 (2.5)	43 (52.4)	52 (83.9)	97 (43.3)
Otherwise	78 (97.5)	39 (47.6)	10 (16.1)	127 (56.7)
Extension contact				
Contact	4 (5.0)	60 (73.2)	62 (100)	126 (56.3)
No contact	76 (95.5)	22 (26.8)	0 (0)	98 (43.8)
Credit Access				
Yes	2 (2.5)	16 (19.5)	1 (1.6)	19 (8.5)
No	78 (97.5)	66 (80.5)	61 (98.4)	205 (91.5)
Labour Source				
Family labour	39 (48.8)	11 (13.4)	14 (22.6)	64 (28.6)
Hired labour	6 (7.5)	14 (17.1)	8 (12.9)	28 (12.5)
Both	35 (43.8)	57 (69.5)	40 (64.5)	132 (58.9)

Field Survey (2018)

The mean size of a farmer's household in the forest zone, transition zone and savannah zones were observed to be approximately 12, 9 and 7 respectively. This is captured as the total number of individuals that live with and are under the care of the farmer and not limited to only blood relations. The maximum household size observed from the entire sample was a household size of 40 in the savannah zone and the minimum was 1. The average distance between a farmers' house to the farm in the three ecological zones were 7.28km for the savannah zone, 5.71km for the transition zone and 3.65km for the forest zone. The observed maximum distance was 30km and the least distance was 0 which represented farmers who lived on their farms.

According to table 4.2, the number of respondents sums up to 202 which forms 90.2% of the entire sample from all three ecological zones. The total number of female farmers interviewed was 22 representing only 9.8% of the entire sample. This result implies that males dominate the maize farming industry in all the three ecological zones under study. The usual role of most women in all the ecological zones were in the provision of various supporting roles in the production process. Most of the productive resources like land and capital were mostly owned by men so very few women owned land that they could use for farming. Their main roles involved fetching water during weedicide and pesticide applications, planting of seeds and assisting during harvest. This finding is consistent with Kuwornu *et al.* (2013) that found that more males than females were engaged in maize farming.

The results also showed that out of the 224 farmers interviewed, 210 were married leaving only 14 farmers who were either single, divorced or widowed. Marriage is essential in farming communities because it provides an avenue for procreation which generates family

labour base for future farming activities. The land tenure system is an important element that affects agricultural production in every society. Only 10 farmers representing 4.5% of the entire sample owned the lands on which they cultivate their maize. Out of the 10 farmers that owned their own lands, 7 of them were from the forest zone with 2 from the transition zone and only 1 from the savannah zone. 77 farmers rented the land on which they produce, 85 were farming on family land and 52 were farming on borrowed lands with the condition of sharing their harvest with the land owners.

According to the results the number farmers who belonged to FBO's in the savannah, transition and forest zones were 2 farmers, 43 farmers and 52 farmers respectively. The remaining 78, 39 and 10 from the three respective zones were not members of any FBO. It was observed that very few farmers in the savannah zone were members of any FBO at all. Being part of an FBO is assumed to enhance the sharing of information on improved technologies and make input acquisition easier (Mukhtar, 2012). The reason for not joining FBO's according to farmers was due to poor leadership and lack of commitment to the course exhibited by other members.

Looking at agricultural extension services, only 4 farmers in the savannah zone had access to extension contact the rest of the 74 farmers had no extension contact. All farmers interviewed in the forest zone had extension contact but only 60 farmers from the transition zone had extension contact with the remaining 22 not having any. According to Nyagaka *et al.* (2010), farm households had a mean of one extension visit per year. Farmers that who engage new technologies in the production need adequate training to be able to adapt to technological changes with time. Quality extension service is required in all the study areas to boost the efficiency of farmers to aid in achieving maximum output potentials.

The results also show that only 19 farmers have access to credit. The remaining 205 farmers representing 91.5% of the entire sample have no access to credit. Access to credit is an important factor that helps improve the performance of agricultural production as it ensures that farmers are able to purchase inputs necessary for production (Onumah *et al.*, 2013). About 28.6% of the entire sample use only family labour for their farm activities, while 12.5% use only hired labour for production. Majority of the farmers interviewed (58.9%) use both family and hired labour for their farming activities. Farmers who use family labour say they do so because it eases the financial burden they would have incurred if they used a lot of hired labour. According to Akanni & Dada (2012), hired adult males accounted for 69.0% of total labour use in agricultural production. Comparatively the transition zone used more family and hired labour altogether. The savanna zone used the least amount of hired labour which stood at a minimum 6 people.

4.3 Summary Statistics of Output and Input Variables.

The mean output for cultivators of maize from the savannah zone was found to be 1428.61 kg per hectare (i.e. about 1.43Mt/Ha) as presented in Table 4.3. This falls below the national average yield of 1.9Mt/Ha and achievable potential of 6.0Mt/Ha (SRID). This was achieved by employing an average of 45.49 man-days of labour, an average seed quantity of 22.78kg per hectare, 239.68 kg of fertilizer per hectare and an average of 4.65 kg of intermediate input per hectare. Minimum and maximum yields of maize in the savannah zone were observed to be 250kg and 3333.33kg per hectare respectively. These were achieved with 7.71 to 75.00 man-days of labour per hectare; 12.86 to 54.71 kg of seed per hectare; 2.50 to 750 kg of fertilizer per hectare and 1.25kg to 16.25 kg of intermediate input per hectare.

Table 4.3 Statistics of output and input variables

Variable	Savannah Zone	Transition Zone	Forest Zone	Pooled
Output (Kg/ha)				
Mean	1428.61	938.98	854.48	1090.46
Std. Dev	752.93	481.45	415.23	630.29
Minimum	250.00	187.50	250	187.50
Maximum	3333.33	3458.33	3000	3458.33
Labour (man-day/ha)				
Mean	45.49	40.17	35.77	40.85
Std. Dev	16.44	16.02	11.69	15.54
Minimum	7.71	7.92	10.76	7.71
Maximum	75.00	73.96	64.58	75.00
Seed (Kg/ha)				
Mean	22.78	25.66	22.96	23.88
Std. Dev	4.78	5.89	5.06	5.44
Minimum	12.86	11.50	10.00	10.00
Maximum	45.71	35.00	32.50	45.71
Fertilizer (Kg/ha)				
Mean	239.68	137.33	192.43	189.13
Std. Dev	111.74	120.17	161.15	136.67
Minimum	2.50	11.25	1.88	1.88
Maximum	750	590.91	750.00	750.00
Intermediate input (GHC/ha)				
Mean	4.65	9.07	11.94	8.54
Std. Dev	1.97	5.00	6.47	5.75
Minimum	1.25	0.83	1.00	0.83
Maximum	16.25	25.00	30.00	30.00

Source: Field Survey (2018)

In the transition zone, the average output was found to be 938.98 kg per hectare by engaging an average of 40.17 man-days of labour per hectare, 25.66kg of seed per hectare, an average of 137.33kg of fertilizer and incurring an average 9.07 kg of intermediate input per hectare. Minimum and maximum yields of maize in the transition zone were observed to be 187.50 kg and 3458.33 kg per hectare respectively. These were achieved with 7.92 to

73.96 man-days of labour per hectare; 11.50 to 35.00 kg of seed per hectare; 11.25 to 590.91 kg of fertilizer per hectare and 1.25kg to 16.25 kg of intermediate input per hectare.

For the forest zone, the average output of maize was estimated to be 854.48 kg per hectare. This was realized by achieved by using an average of 35.77 man-days of labour per hectare, 22.96 kg of seed per hectare, 192.43 kg of fertilizer per hectare and an average 11.94 kg of intermediate input per hectare. Minimum and maximum yields of maize in the forest zone were observed to be 250.00 kg and 3000.00 kg per hectare respectively. These were achieved with 10.76 to 64.58 man-days of labour per hectare; 10.00 to 32.50 kg of seed per hectare; 1.88 to 750.00 kg of fertilizer per hectare and 1.00 kg to 30.00 kg of intermediate input per hectare.

The pooled data however showed that the average yield across the three zones was 1090.46 kg per hectare which was obtained employing 40.85 man-days of labour per hectare, 23.88 kg of seed per hectare, 189.13 kg of fertilizer per hectare and 8.54 kg per hectare of intermediate input. A study by Oppong *et al* (2014) observed outputs of maize to range between 3375 kg/ha and 6750 kg/ha and found the average output to be 1975 kg/ha. The average output of 1975 kg/ha was attained by employing 67.95 man-days/ha of labour, 21.35 kg of seed per hectare, 8.57 liters/ha of herbicide and average cost of GHC170.98 on intermediate inputs.

The variable 'intermediate input' encapsulates the total quantities of weedicide, pesticides and other agrochemicals used during the production season. Different combinations of NPK, Urea and Sulphate of Ammonia fertilizers were used for production in the three ecological zones.

4.4 Results of Hypotheses tested

Hypotheses were each checked in order to assess the amplex of the predetermined functional form, the possible existence of inefficiency, and the importance of the external factors in explaining the inefficiency in maize production in the study areas. The suitability of adopting the Metafrontier model for the study was also checked. The results of these tests are shown in table 4.4.

The initial hypothesis tested the suitability of the Cobb-Douglas functional form for the dataset at the group levels and in the pooled model. The hypothesis is rejected in favour of the translog functional form but is only accepted in for the savannah zone. This means the translog functional form best suits the dataset in the transition zone, forest zone and in the overall data set yet does not best suit the savannah dataset.

The second null hypothesis proposes the absence of inefficiency effects for all the models. The test revealed that there were inefficiency effects in all models but for the forest zone. This is probably due to the very high technical efficiency score obtained for that ecological zone.

The third hypothesis was to test the half normal distribution against the assumption of a truncated normal distribution. The decision to adopt the half normal distribution was rejected for all the datasets except for the savannah zone which had its test statistic being lower than the critical value.

Table 4.4 Hypothesis test for group and metafrontier model

Hypothesis	LR Statistics (λ)	LR Critical Value	Decision
$H_o : \beta_{ij} = 0$			
Savanna	11.07	18.31	Accept H_o
Transition	34.00	18.31	Reject H_o
Forest	24.03	18.31	Reject H_o
Pooled	38.48	18.31	Reject H_o
$H_o : \gamma = \delta_0 = \delta_1 = \dots, = \delta_{11} = 0$			
Savanna	29.93 ^a	21.74 ^b	Reject H_o
Transition	26.23 ^a	21.74 ^b	Reject H_o
Forest	12.55 ^a	21.74 ^b	Accept H_o
Pooled	29.49 ^a	21.74 ^b	Reject H_o
$H_o : \delta_0 = \delta_1 = \dots, = \delta_{11} = 0$			
Savanna	2.17	21.03	Accept H_o
Transition	25.56	21.03	Reject H_o
Forest	27.28	21.03	Reject H_o
Pooled	29.49	21.03	Reject H_o
$H_o : \delta_1 = \delta_2 \dots, = \delta_{11} = 0$			
Savanna	32.11	19.68	Reject H_o
Transition	25.56	19.68	Reject H_o
Forest	27.28	19.68	Reject H_o
Pooled	29.49	19.68	Reject H_o
$H_o : \gamma = 0$			
Savanna	44.65 ^a	9.50 ^b	Reject H_o
Transition	32.57 ^a	9.50 ^b	Reject H_o
Forest	39.83 ^a	9.50 ^b	Reject H_o
Pooled	38.52 ^a	9.50 ^b	Reject H_o
$H_o : f_{LV}(X; \beta_{LV}) = f_{IV}(X; \beta_{IV})$			
Pooled only	138.69	32.20	Reject H_o

Source: Field survey 2018. ^a Ox output estimates for one sided error test obtained from the ML estimation. ^b Critical Values at 0.05 for the test of hypothesis under the mixed chi-square distribution.

The fourth hypothesis which tested whether the exogenous variables included in the inefficiency model had no effects on farmers' efficiency level was also rejected. This proved that the combined effect of the random variables hypothesized in the inefficiency

model are statistically significant in explaining farm inefficiency in the group and pooled models.

The final hypothesis which is of great importance to this study tests the assumption that the technologies used in the three ecological zones are the same. If the three ecological zones shared the same technology, there would be no need to estimate a Metafrontier for the pooled model. With 56 degrees of freedom, the likelihood ratio was 138.69 which was far above the critical value of 32.20 at 1% significance level. Hence we reject the null hypothesis.

4.5 Productivity Estimates (Output Elasticity and Returns to Scale)

Table 4.5 indicates that all input factors emphatically increase yield levels in the transition and forest zones but the intermediate input proved to contribute negatively to output in the savannah zone and in the pooled model. This is an indication that, if we want to increase output in the transition and forest zones we must increase all the inputs used for maize production but if we intend to increase output in the savannah zone then we must reduce the quantity of intermediate input used per hectare for production. The greatest share of productivity went to seed in the savannah zone but went to labour in the forest and transition zones and also in the pooled model. A percent increase in labour, fertilizer and seed will lead to a 0.007%, 0.25% and 1.63 increase in output respectively. Whereas a percent increase in intermediate input will lead to a 0.7% decrease in output in the savannah zone. In the transition zone, a percent increase in labour, fertilizer, intermediate input and seed will lead to a 0.42%, 0.13%, 0.06% and 0.41% increase in output respectively. In the forest zone, a percent increase in all the aforementioned inputs will cause a positive increase of 0.67%, 0.27% 0.37% and 0.58% in the levels of output respectively.

The results of this study confirms what Ayinde *et al.* (2015) observed in Nigeria in a study of ‘the determinants of technical efficiency and varietal-gap of rice’. It was observed that a positive relationship exists between labour, fertilizer and output of rice. A research conducted by Asravor *et al.* (2015) showed that all inputs contribute positively to output but for seed input. Another study

Table 4.5 Output elasticities and returns to scale from group and pooled frontiers

Variable	Savannah Zone	Transition Zone	Forest Zone	Pooled
LogLabour	0.0071 (0.987)	0.4228 (0.013)**	0.6687 (0.000)***	0.4581 (0.000)***
LogFertilizer	0.2563 (0.368)	0.1253 (0.117)	0.2683 (0.002)***	0.2819 (0.000)***
LogIntermediate Input	-0.7002 (0.345)	0.0585 (0.351)	0.3696 (0.000)***	-0.0270 (0.602)
LogSeed	1.6346 (0.019)**	0.4143 (0.356)	0.5837 (0.000)***	0.0406 (0.790)
RTS	1.2	1.02	1.89	0.75

Source: Field survey 2018. Note: Standard deviations in parenthesis; ***, ** and * denote significance at 1%, 5% and 10% respectively.

on the productivity potential of cocoa by Binam *et al.*, (2008) found that all inputs contributed positively to output. The summation of all partial elasticities of output regarding the different sources of inputs used in the three ecological zones for maize production exhibit increasing returns to scale but exhibit a decreasing returns to scale in the pooled sample. The coefficients 1.2, 1.02 and 1.89 means a simultaneous percent increase in every input variable will cause a 1.2%, 1.02% and 1.89% percent increase in maize output in the savanna zone, transition zone and in the forest zone respectively. This

proves that when farmer efficiency is improved in the long run, they will still have enough room to increase their scale of production in all the three ecological zones.

4.6 Parameter Estimates of the Stochastic and Metafrontier Models

According to table 4.6 the study undertaken found that, some input variables are statistically significant in some ecological zones and not significant in others. The transition zone however had all the input variables being statistically significant. Labour, fertilizer, intermediate input and seed were all statistically significant at 1% in the transition zone. Only seed was statistically significant in the savannah zone with a significance level of 5%. In the Forest zone only labour was found to be significant at 5% even though all other inputs affected output positively in that ecological zone. These results are an indication that the allocation of some of these inputs were productive, therefore consciously increasing the inputs that had significantly positive effects on output in the three respective ecological zones will enable increases in maize output.

Kuwornu *et al.*, (2013) found a negative relationship between the contributions of seed and fertilizer to maize output but this study however observed a positive relationship between the contributions of seed and fertilizer to maize output in all three ecological zones. Sienso *et al.*, (2013) observed a positive relationship between weedicides and pesticides to maize output but the variable intermediate input which includes pesticides and weedicides happen to contribute negatively to output in the savanna zone but was consistent to the findings in the transition and forest zones. The results in the above table also show that an exponential increase in labour in the transition zone and an exponential increase in fertilizer will have a positive effect on output. This means that labour and fertilizer are inputs that are being

underutilized in the production process and more of these inputs can be employed to increase output levels.

Table 4.6 Parameter estimates of the stochastic and metafrontier models

Variable	Parameter	Savannah	Transition	Forest	Pooled	Meta
Constant	β_0	0.1967 (0.27)	-0.1361 (0.04)***	-0.2518 (0.06)***	-0.0459 (0.04)	0.4591 (0.12)
LogLabour	β_1	0.0071 (0.34)	0.6687 (0.11)***	0.4228 (0.14)**	0.4581 (0.09)***	0.0947 (0.17)
LogFertilizer	β_2	0.2563 (0.30)	0.2683 (0.05)***	0.1253 (0.08)	0.2819 (0.04)***	0.2601 (0.14)
LogIntermediate input	β_3	-0.7002 (0.66)	0.3696 (0.07)***	0.0585 (0.09)	-0.0270 (0.06)	-0.1638 (0.14)
LogSeed	β_4	1.6347 (0.83)**	0.5837 (0.14)***	0.4143 (0.44)	0.0406 (0.15)	-0.4216 (0.35)
LogLabour_sq	β_5	-0.6555 (0.43)	0.1851 (0.17)	1.1665 (0.52)***	0.1169 (0.19)	-0.2337 (0.27)
LogFertilizer_sq	β_6	-0.1351 (0.13)	0.1891 (0.08)	0.1063 (0.04)**	0.1699 (0.03)***	0.1870 (0.11)
LogIntermediate input_sq	β_7	-0.8051 (0.75)	-0.0342 (0.10)	0.1240 (0.11)	-0.0257 (0.09)	0.0342 (0.23)
LogSeed_sq	β_8	0.5579 (1.57)	-0.5368 (0.26)**	1.0996 (0.324)	0.1109 (0.27)	0.8515 (0.68)
LogLab*LogFert	β_9	-0.3559 (0.32)	-0.0816 (0.12)	-0.1748 (0.09)*	-0.0523 (0.07)	-0.0786 (0.16)
LogLab*LogInt	β_{10}	0.0653 (0.27)	-0.2862 (0.14)**	-0.0522 (0.18)	0.0311 (0.10)	0.2311 (0.17)
LogLab*LogSeed	β_{11}	0.6548 (1.05)	0.2165 (0.23)	-0.3164 (1.00)	0.4354 (0.33)*	0.1948 (0.59)
LogFert*LogInt	β_{12}	0.1352 (0.39)	0.1175 (0.07)*	-0.1042 (0.06)*	-0.1283 (0.04)***	0.0159 (0.10)
LogFert*LogSeed	β_{13}	0.9000 (0.92)	0.0045 (0.21)	-0.3220 (0.32)	-0.3954 (0.17)**	-0.5953 (0.49)
LogInt*LogSeed	β_{14}	-1.1838 (1.13)	0.4948 (0.23)**	-0.0051 (0.40)	0.4457 (0.19)***	0.7225 (0.44)
Log likelihood						
		-42.6981	6.7448	-3.6827	-112.2055	
Gamma						
		0.52		0.16	0.107	

Source: Authors own estimation, 2018. Note: Standard deviations are in parenthesis; ***, ** and * designate significance at 1%, 5% and 10% respectively.

4.7 Summary on Technical Efficiencies (TE) and Environmental-Technology Gap Ratios (ETGRs)

The Metafrontier model allows the estimation of environmental-technology gap ratios which indicate the gap between the prevailing technology within one ecological zone and the technology available to the whole maize industry and the interactions between these technologies and the ecological zone. A high environmental-technology gap ratio (ETGR) implies a small gap between the individual frontiers and the Metafrontier. The Metafrontier also informs on the productivity potential of a given unit given the maximum potential of the whole industry. The ETGR values obtained from the Metafrontier analysis also allows us to compare the technical efficiency levels of producers in the forest zone, savannah zone and transition zone.

The technical efficiency scores for the pooled stochastic frontier model ranged from a minimum of 0.33 to a maximum of 1.00; the mean technical efficiency for the pooled model was 0.95. According to table 4.7, the mean technical efficiency of the savannah, transition and forest zones were observed to be 0.78, 0.97 and 0.97 respectively. This means at the means, maize producers within the savannah zone fall below their group frontier by 22% while their counterparts in the transition and forest zones are only 3% below their individual group frontiers. A study by Abdulai *et al* (2013) observed the mean technical efficiency estimate for maize farmers in northern Ghana (savannah zone) to be 74% with 12 and 99% as the minimum and maximum, respectively. This value is approximately consistent with the observed value in this study. This study shows that maize producers within the three respective zones achieve 78%, 97% and 97% of their potential frontier outputs with their current inputs and available technology. Thus if maize cultivators these three study areas are to achieve 100% of their maximum frontier potential,

they must direct efforts towards bridging the gap that lies between their present performance levels and their highest potential performance by reducing the effects of some factors that promote inefficiencies in production. The least performing producers from the savannah zone, transition zone and forest zone had technical efficiency scores of 0.16, 0.36 and 0.38 respectively. Which means they achieved 16%, 36% and 38% of their potential outputs within their respective ecological zones. The highest

Table 4.7 Environmental-technology gap ratios and technical efficiency estimates

	Mean	Minimum	Maximum	Std. Dev
Environmental-Technology Gap Ratios				
Savannah Zone	0.75	0.18	0.98	0.17
Transition Zone	0.61	0.06	1.00	0.21
Forest Zone	0.47	0.11	0.82	0.14
Pooled	0.63	0.06	1.00	0.21
Technical Efficiency (Group frontier)				
Savannah Zone	0.78	0.16	0.99	0.20
Transition Zone	0.97	0.36	1.00	0.10
Forest Zone	0.97	0.38	1.00	0.11
Pooled	0.95	0.33	1.00	0.11
Technical efficiency (Metafrontier)				
Savannah Zone	0.56	0.13	0.95	0.21
Transition Zone	0.60	0.06	1.00	0.21
Forest Zone	0.45	0.11	0.82	0.15
Pooled	0.59	0.02	1.00	0.22

Source: Authors own estimation (2018)

performing farmers from the savannah zone had a technical efficiency score of 0.99, while the highest performers from transition and forest zones both had technical efficiency scores of 1.00 which meant that they were fully efficient in their production. As opined by Onumah *et al.*, (2013), “gains of technical efficiency translate into improvements in farm household incomes and farmers profit from such gains directly”.

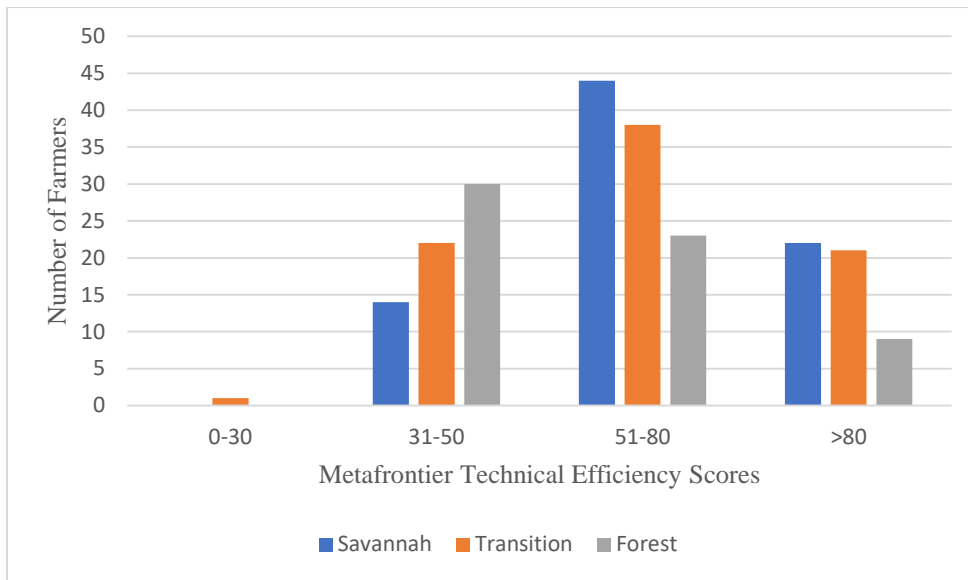
The value of the ETGR is a measure of the gap between a given technology (in one ecological zone) and the technology available to the whole maize industry and how they best suit each ecological zone given vector inputs (Villano *et al.*, 2010 and BATESSE *et al.*, 2004). This only means that if the maize producers were technically efficient in relation to their group frontiers at the farm level, they can still increase their output by closing the gap that lies between their present performance and the potential by adopting the best practice technology that suits their ecological zone in which they operate. Maize producers within the savannah zone, transition zone and forest zones had mean ETGRs of 0.78, 0.61 and 0.47 respectively. The implication of this results is that if the average maize producers in the savannah, transition and forest zones were to be technically efficient (relative to their group frontiers), they could still increase output levels by closing a gap of 22%, 39% and 53% respectively if they were to employ the best practice technology for the whole maize industry. Although there is some scope to increase yield through management training to improve the usage of current inputs and practices, closing the technology gap would require innovations in technologies and policies particularly adapted for the dry, the tropical, the more traditional regions. These include new seeds adapted to drier conditions and effective methods of weed, insect, and disease control (Donnet, L. *et al.* 2017).

The results show that the maize producers from the savannah zone were found to be closest to the Metafrontier than their counterparts in the transition and forest zone. All things being equal, maize producers from the savannah zone will attain their highest possible output for maize cultivators in Ghana faster than their counterparts in the other two zones. Producers in the transition zone will be the second to reach their maximum potential with the forest zone producers being the last to close the gap. This observation with respect to the forest

zone may be due to reduced familiarity to advanced input technologies and the widespread army worm disease that was rather rampant within this study area during the period of this study.

Furthermore, the mean relative technical efficiency scores with respect to the Metafrontier for the forest savannah and transition zones were 0.45, 0.56 and 0.60 respectively. This means that maize producers operating in the transition zone are the most technically efficient producers among all farmers from the three ecological zones. The next best efficient group of producers were found to be maize farmers from the savannah zone. The least efficient group were farmers from the forest zone. These findings suggest that farmers engaged in maize cultivation in the forest zone are more competitive than those in the transition and savannah zones. According to Nkamleu *et al.*, (2006), the result of the constraints faced in individual linear programming problems are a part of those faced in a Metafrontier linear programming and this causes the technical efficiency scores relative to the Metafrontier to be lower than those obtained from the individual stochastic frontiers.

Figure 4.1 Distribution of the meta-frontier technical efficiency scores



Source: Authors own computation

The farmers within the savannah zone had most of their technical efficiencies relative to the Metafrontier (55%) being clustered around a range of 51-80% with 27.5% of farmers having their efficiencies above 80% as presented in table 4.8. The transition zone had most of their technical efficiencies of farmers (46.3%) relative to the Metafrontier also being clustered around a range of 51-80% with 25.6% of farmers having their efficiencies above 80%. Farmers in the forest zone had most of their technical efficiencies relative to the Metafrontier (48.4%) being clustered around a range of 31-50% with only 14.5% of farmers having their efficiencies above 80%. It can be observed that producers in the savannah and transition zones are far more resourceful in terms of their input use in production than maize farmers from the forest zone.

Table 4.8 Percentage distribution of Metafrontier technical efficiency scores

Score	Savannah	Transition	Forest
0-30	0	1.2	0
31-50	17.5	26.8	48.4
51-80	55	46.3	37.1
>80	27.5	25.6	14.5

Source: Authors own computation, based on survey data, 2018.

4.8 Determinants of Technical Inefficiency

The nature of the efficiency change as given by the inefficiency model is important in this study. According to Onumah *et al.*, (2013), technical efficiency scores of production units are required but not sufficient for policy interventions, hence there is reason to locate factors that promote variations in technical efficiency estimates. From the results of the inefficiency model, it is evident that FBO membership is significant in the savannah zone. Significant factors in the transition zone included education, household size, experience, extension, land ownership, available surplus market and access to credit. Within the pooled model, age and all variables that were significant in the transition zone except for surplus market were observed to significantly affect the efficiency of maize farmers. The results of the inefficiency model are presented in table 4.8.

According to table 4.8 the coefficient of formal education in the savannah, transition and forest zones are negative. It is significant at 1% in the transition zone but not significant in the others. This is an indication that increased years of formal education improves farmers' ability to allocate input resources efficiently in maize farming across all three ecological

zones. The expected apriori sign was observed even though the other two zones were not significant. Nyakaga *et al.*, (2010) assumed that farmers with more education have the ability to perceive, interpret and respond to

Table 4.9 Parameter estimates for the technical inefficiency model

Variable	Savannah	Transition	Forest	Pooled
Constant	-0.8158 (3.67)	-6.4039 (572.1)	1.2243 (1018)	-1.6102 (2.78)
Age	-0.0381 (0.03)	-0.0222 (25.48)	1.1067 (59.40)	-0.0616 (0.04)***
Education	-0.2023 (0.17)	-20.0637 (1.23)***	-10.8095 (555.2)	-0.4185 (0.31)**
Household size	0.0374 (0.03)	1.9527 (61.43)***	8.9282 (363.8)	0.0362 (0.03)*
Experience	0.0226 (0.02)	-1.5653 (39.56)***	-2.9093 (122.6)	0.0537 (0.03)**
Extension	-0.2377 (0.12)	1.2982 (19.82)***	-6.9058 (309.5)	-0.5250 (0.18)***
FBO member	-17.978 (0.000)***	-7.2771 (479.6)	8.7872 (321.9)	0.4619 (0.79)
Land ownership	0.2324 (0.48)	-2.4466 (114.7)***	-6.1141 (487.2)	0.8159 (0.51)***
Major occupation	-0.5177 (0.56)	-4.9521 (359.3)	-20.9006 (1636)	0.4804 (0.77)
Surplus market	0.3843 (0.60)	-15.7705 (383.2)***	-16.9489 (771.2)	-0.1987 (0.72)
Access to credit	1.2960 (1.46)	-25.6725 (12.83)***	12.1165 (1183)	2.9259 (1.46)**

Source: Field Survey, 2018. Note: Standard deviations in parenthesis; ***, ** and * sdesignate significance at 1%, 5% and 10% respectively.

new information and adopt improved technologies like pesticides, fertilizers and improved planting materials much faster than their counterparts with little or no education. Mariano *et al.*, (2010) also observed that education had positive effects on the technical efficiency of maize producers.

The results presented in the Table 4.9 show that the coefficient of experience is negative in the transition and forest zones with the transition zone coefficient being significant at 1%. This proves that farmers with more years of experience in maize farming tend to be more efficient than those with lesser years of experience in these two zones. According to Sienso *et al.* (2013), more years of farming experience is expected to make farmers more efficient since they would have become accustomed to the erratic conditions of agriculture and would be able to predict the right time to sow, the right amount of inputs and the best times to apply these inputs. The savanna zone however had its coefficient being positive which suggest that farmers who had a higher number of years of experience were less efficient. The reason for this observation may be due to the old-fashioned nature of older producers within the savannah zone who may not be keen to adopt new or modern technologies to increase output. This result match finding of Olarinde (2011).

Agricultural extension agents are intermediaries between researchers and farmers. They work as facilitators by communicating new and innovative technology developed by researchers to farmers and also report the problems and needs of farmers back to the researchers. It is therefore expected that an increased extension contacts will lead to an increase in farmers' level of efficiency and increases in output. The study found that increased extension contacts reduced in efficiencies in the savannah and forest zones but increased inefficiency levels in the transition zone. Onumah *et al.*, (2010) and Binem *et al.*,

(2008) also made similar observations that showed that increased extension contacts helped increase efficiency levels. Farmers in the transition may have not been implementing the advisory services provided by the extension agents correctly and that may be the reason for the positive sign of the coefficient for the transition zone.

According to the study FBO membership reduced inefficiencies in the savannah and transition zones but increased in efficiency levels in the forest zone. Even though the coefficient was insignificant in the transition zone it carried a negative sign which showed that farmers that belonged to a farmer based organization in the savannah and transition zones were more efficient than their counterparts who were not members of any FBO. The reason could be attributed to the support from members of the group and training received organization on new and improved methods of production. Farmers who belonged to are more likely to benefit from better access to inputs and information sharing among other producers. This finding is consistent with the findings made by Nyakaga *et al.*, (2010). The reason for the positive sign in the forest zone may be attributed to complains that some members were not committed to the activities of the FBO and were not correctly implementing the training on agronomic practices given them by the organization.

From the results presented in Table 4.8, it is observed that the availability of a surplus market for farmers to sell their produce has a negative sign in the transition and forest zones but has a positive sign in the savannah zone. This means that the availability of a ready market reduces the inefficiencies of farmers in the transition zone and in the forest zone. The coefficient for the surplus market was found to be significant at 1% in the transition zone. Good and promising market conditions motivate farmers to use inputs efficiently to maximize their outputs and eventual gains as they are assured of timely recovery of their

investments after harvesting. This observation agrees with findings of Asravor *et al.*, (2015) and Cobbina *et al.*, (2010) who postulated that dependable access to produce markets spur producers to give their best with a specific end goal to of earning more money, which intend expanded productivity of agriculturists.

Easy access to cash credit may help farmers to purchase production inputs and to hire labour for their farming activities. In effect farmers with access to credit tend to be technically more efficient than their counterparts without access to credit. They have the ability to buy and apply optimal amounts of inputs when necessary during their production season. Maize producers in the transition zone were the only farmers to have their inefficiencies being reduced by access to credit. This is in line with research done by Nyagaka *et al.* (2010) and Binam *et al.* (2008). The remaining savannah and forest zones had the signs on their coefficients being contrary to the aforementioned studies. This was due to the reason that not all the monies received from the credit facilities was directed at farming activities but some were used to pay the school fees of their children and for housekeeping. Access to credit though, only had significant effect at 1% in the transition zone where it reduced inefficiency.

According to the results of this study, the household size carried positive signs in all the three ecological zones under study though it only had significant effects at 1% in the transition zone. This means that the household size of farmers increased the inefficiency of farmers across all zones. This was attributed to the fact that most children, family and other wards living under the care of most of the farmers interviewed were not actively involved or providing labour to support the farmer under who's care they were living.

Age was observed to have a negative coefficient in the savannah and forest zones. This means that the older the farmer in these two ecological zones the more efficient he is. This may be due to the accumulation of years of experience in maize farming as older farmers would have been involved in maize farming longer than their younger counterparts and perhaps older producers may probably have maize cultivation as their only job. The coefficient of age was however positive in the forest zone which means that the older the farmer the more inefficient they are. It is conventionally expected that as farmers age, their level of efficiency reduces because they are not as energetic as they were in their youth to go about their farming activities efficiently. Mariano *et al.*, (2010) observed that older farmers are less efficient compared to younger farmers.

4.9 Constraints faced by maize farmers

Constraints faced by maize farmers in the Savannah zone

According to table 4.10, on-farm disease and pest attacks was the most pressing constraint faced by farmers in the savanna zone with a mean rank of 2.33. It was closely followed by the high cost of production and accessibility to recommended fertilizers both having average ranks each of 2.33 and 4.81. The least most pressing constraint ranked by the farmers in the savanna zone with a mean rank of 9.81 was access to credit with the reason being that most financial institutions were unwilling to give out loans to farmers due to the risky nature of farming within that ecological zone. They attributed these risks to unstable weather conditions and rainfall patterns and possible drought conditions. The test statistics to determine the agreement among respondents using the Kendall's coefficient of concordance are presented in Table 4.11. The results show that the value the Kendall's

Coefficient $W = 0.515$ this means that 51.5% of farmers interviewed within the savanna zone agree with the ranks assigned to the various constraints they face. The asymptotic significance was found to be 0.000 which is less than 0.05. Thus, the null hypothesis that there is no agreement between rankings is rejected and we accept the alternate hypothesis that the rankings agree. Therefore, farmers in the savanna zone can be said to agree to the rankings in Table 4.10.

Table 4.10 Constraints faced by maize producers in Ghana

Constraints	Savannah Zone		Transition Zone		Forest Zone	
	Mean ranks	Ranks	Mean ranks	Ranks	Mean ranks	Ranks
Disease and pest attacks on farm	2.33	1	2.96	2	2.17	1
High cost of production	2.43	2	2.65	1	2.81	2
Accessibility to recommended fertilizers	4.81	3	7.55	9	7.05	8
Challenges of ready market for marketable surplus	5.00	4	5.79	6	6.93	7
Land acquisition and land tenure problems	5.43	5	3.75	3	4.28	3
Transportation to and from farms through to markets	5.46	6	4.20	4	5.90	6
Storage problems and spoilage	6.33	7	5.24	5	4.83	4
Accessibility to improved maize varieties	6.45	8	8.84	10	7.79	9
Accessibility to recommended agrochemicals	6.94	9	7.55	8	8.23	10
Access to credit	9.81	10	5.88	7	4.84	5

Source: Field Survey, 2018

Table 4.11 Table of test statistics

Test Statistics	Savannah Zone	Transition Zone	Forest Zone
N	80	82	62
Kendall's W	0.515	0.509	0.471
Chi-Square	370.604	375.537	262.711
Df	9	9	9
Asymptotic Sig.	0.000	0.000	0.000

Source: Authors own estimation, 2018

Constraints faced by maize farmers in the Transition zone

From Table 4.10, high cost of production was the most pressing constraint faced by farmers in the transition zone with a mean rank of 2.65. It was followed by the diseases and pest attack and land acquisition and land tenure problems having average ranks of 2.96 and 3.75 each. The least most pressing constraint ranked by the farmers in the transition zone was accessibility to improved maize varieties which had a mean rank of 8.84. The test statistics to determine the agreement among respondents are presented in table 4.11. The results show that the value the Kendall's Coefficient $W = 0.509$. This means that 50.9% of farmers interviewed within the transition zone agree with the ranks assigned to the various constraints they face. The asymptotic significance was found to be 0.000 which is less than 0.05. Thus, the null hypothesis that there is no agreement between rankings is rejected and we accept the alternate hypothesis that the rankings agree. Therefore, farmers in the transition zone can be said to agree to the rankings in Table 4.10.

Constraints faced by maize farmers in the Forest zone

From table 4.10, on-farm disease and pest attacks was the most pressing constraint faced by farmers in the forest zone with a mean rank of 2.65. It was followed by high cost of production and land acquisition and land tenure problems carrying average ranks of 2.81 and 4.28 each. The least most pressing constraint ranked by the farmers in the forest zone was accessibility to recommended agrochemicals and had a mean rank of 8.23. The test statistics to determine the agreement among respondents are presented in table 4.11. The results show that the value the Kendall's Coefficient $W = 0.471$. This means that 47.1% of farmers interviewed within the forest zone agree with the ranks assigned to the various constraints they face. The asymptotic significance was found to be 0.000 which is less than 0.05. Thus, the null hypothesis that there is no agreement between rankings is rejected and the we accept the alternate hypothesis that the rankings agree. Therefore, farmers in the forest zone can be said to agree to the rankings in Table 4.10.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1 Introduction

This chapter of the study presents a brief review and draws conclusions on the major findings presented in the previous chapter. Based on the findings of the study, policy recommendations are made for future development interventions.

5.2 Summary of the Study

The aim of this study was to comparatively assess the technical efficiencies and technology gap ratios of maize farmers across three different ecological zones in Ghana to determine whether spatial difference by location in a particular ecological zone affects the efficiency level of farmers who are engaged in maize cultivation in Ghana. The three ecological zones selected for the study included the forest zone, the transition zone and the savannah zone. The study employed the basic stochastic frontier production model and the stochastic Metafrontier model to compute productivity levels of farmers who are engaged in maize production in the three study areas, to estimate their various efficiency scores and to compute their technology gap ratios. The determinants of farmers' inefficiencies were also identified. The stochastic Metafrontier envelopes the individual group frontiers of the three ecological zones and provides an avenue for ETGRs to be computed. The technical efficiency scores for the three different ecological zones relative to the Metafrontier are also estimated. These relative technical efficiencies and technology gap ratios are very important signals for policy initiatives.

The translog and Cobb-Douglas functional forms were both tested for their suitability. The translog however proved to be the better fit for the datasets and was hence chosen for the study. A test was conducted to determine the relevance of the Metafrontier model and the decision was taken in favour of the model. The total effect of the exogenous factors explained variations in efficiency. Cross sectional data was collected on 224 farmers with 80 farmers representing the savannah zone, 82 farmers representing the transition zone and 62 farmers from the forest zone. The OX Metrics program was used to analyze the raw information that was collected during the field survey.

According to this study, technical inefficiencies do exist among farmers who cultivate maize in all three ecological zones. However, the existence of these inefficiencies and environmental restrictions proposes that they have a managerial gap that they can close with management of current investments in inputs and agronomic practices to further increase output. The study also showed that factors what were hypothesized in the inefficiency model collectively influenced the technical efficiency of producers in all the three research areas but were highly significant in the transition zone. Farmers from the transition and forest zones proved to be more efficient in their production than their counterparts from the savannah zone. Education was observed to have a reducing effect on the inefficiency of maize farmers across all three ecological zones. Age of farmer, experience, extension, FBO membership, land ownership, the major occupation of the farmer and an available surplus market were all observed to have negative or positive effects on the inefficiency of maize farmers depending on the ecological zone in which they operate.

5.3 Conclusion

Key input variables like labour, fertilizer and seed positively influenced the productivity of farmers who were involved in maize production in all the three study areas. Intermediate input which was constituted of weedicide and pesticides exhibited an adverse effect on productivity in the savannah zone because it was being overutilised. The study revealed returns to scale values of 1.2, 1.02, 1.89 and 0.75 for the savannah zone, transition zone, forest zone and the pooled dataset respectively. These three ecological zones all showed increases in yields as the scale of production increased. The result being that the scale of production in the three ecological zones can be increased to achieve optimal levels of production. The pooled model however exhibited a decreasing returns to scale. This is an indication that although the group frontiers exhibited increasing returns to scale, more effort must be directed towards improving upon management practices to enhance productivity.

The mean technical efficiency scores of for each of the three aforementioned ecological zones were 0.78, 0.97 and 0.97 with the pooled model achieving a mean technical efficiency score of 0.95. This means that producers in the savannah, transition and forest zones are able to achieve 78%, 97% and 97% of their maximum output potential given the available inputs and level of technology at their disposal within their specific ecological zones. The mean environmental-technology gap ratios for the three ecological zones were computed to be 0.75, 0.61, 0.47 and 0.63 for the savannah zone, transition zone, forest zone and the pooled dataset respectively. This simply means that the savannah zone is closest to the meta-frontier which represented the best practice technology available in the maize industry for that ecological zone. The remaining environmental-technology gap that lies

between the Metafrontier and the savannah, transition, forest zones and the pooled dataset was 0.25, 0.39, 0.53 and 0.37 respectively.

The average technical efficiency relative to the Metafrontier for the savannah zone, transition zone and forest zone were 0.56, 0.60 and 0.45 respectively. This implies that, farmers involved in maize cultivation in the transition zone are the most technically efficient producers followed by their counterparts from the savannah zone whereas the least technically efficient producers were maize farmers from the forest zone. Therefore, potential for additional expansion in yield to meet the highest possible potential yield is substantially higher in the forest zone than in the other two ecological zones.

Farmers in the all the three ecological zones in this study are not able to achieve 100% of their potential output with their current input levels due to the presence of technical inefficiencies. The factors within the inefficiency model are important in explaining the inefficiencies present in maize production in the study areas. In the savannah zone, age of farmer, education, extension, FBO membership and major occupation reduce inefficiency but factor like household size, experience, land ownership, surplus market and access to credit increase inefficiency levels. In the transition zone, only household size and extension increased inefficiency whereas all other factors had a decreasing effect on inefficiency. Then for the forest zone, age household size, FBO and access to credit increased inefficiency levels while education, experience, extension, land ownership, major occupation and surplus market had reducing effects on inefficiency.

5.4 Policy Recommendations

This study recommends that maize producers in all three ecological zones increase the scale of production in order to increase output. Measures that enhance productivity can be adopted by farmers to improve upon output levels. Some of these factors include timely application of fertilizers, pesticides and weedicides in optimal proportions as directed by extension agents and the application of effective on-farm managerial practices. Farmers should be educated and trained to plant in rows, adhere to recommended plant densities and apply effective postharvest practices to avoid postharvest losses especially in the savannah and forest zones.

This study shows that maize output in the savannah zone can be increased without increasing input resources or the need for new technologies, therefore this study recommends that efforts should be directed at reducing inefficiencies that are present in the maize production process within that ecological zone. Extension officers and other advisory services should endeavor to promote quality extension delivery that focuses on allocating input in optimal quantities to maximize output of maize farmers.

Furthermore, this study demonstrates that there is more space for technological improvement especially in the forest zone where the technology gap is largest compared to the other two ecological zones. The Ministry of Food and Agriculture should design training programs that educate farmers on the benefits of adopting new and improved methods and planting material. Farmers should be given practical field demonstrations to prove that improved and resistant seed varieties and other input technologies that are recommended to them can actually increase output when applied effectively.

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APPENDIX

UNIVERSITY OF GHANA

DEPARTMENT OF AGRICULTURAL ECONOMICS AND AGRIBUSINESS

**COMPARATIVE ANALYSIS OF TECHNICAL EFFICIENCY AND
PRODUCTIVITY DIFFERENCES IN MAIZE FARMING IN GHANA**

QUESTIONNAIRE

This questionnaire has been designed purposely to address the above topic in partial fulfillment for the award of a Master of Philosophy Degree in Agricultural Economics at the University of Ghana, Legon. Any information provided by respondents will be used for data analysis in respect of the above mentioned topic.

Identification Code

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Name of Enumerator:.....

District:.....

Town:.....Date...../.....
.../2018

Name of farmer:.....

Farmer's contact number:.....

SECTION A: Socio-Economic Characteristics of Maize farmers

A1. Gender: 1 = Male [] 0 = Female []

A2. Age of maize farmer:years

A3. Marital status of farmer: 0 = Single [] 1 = Married [] 2 = Divorced/Separated []
3 = Widowed []

A4. Religion: 1 = Christian [] 2 = Muslim [] 3 = Traditional []
4 = Others(specify).....

A5. Level of education: 0 = No formal education [] 1 = Primary education [] 2 = JHS []

3 = SHS/Vocational/Technical [] 4 = Tertiary [] 5 = Others(specify) []

A6. Please indicate the number of years spent in school.....

A7. Household sizeperson(s)

Table 1: Household Size

Number of adults above 18 years		Number of children below 18 years	
a. Males	b. Females	a. Males	b. Females

SECTION B: Questions on maize cultivation

B1. How many years have you been involved in maize production?

B1.1 Please indicate the number of acres you allocated to maize production in the 2017 production seasons

a. Major season..... b. Minor season.....

B2. What type of variety of maize was used? 0=Local variety [] 1 = Improved variety [] 2 = Both []

Table 2: Variety of maize seeds 2017

Improved variety	Local variety	
		Abontem, Omankwan, Aburohemaa, WangDataa, Golden jubilee, Okomasa, Akposoe, Dobidi, Aburotia, Obaatanpa, Mamaba, Dadaba, Cidaba, Etubi, etc.

B2.3 Quantity of seed planted.

Table 3 Seed Usage 2017

Improved variety			Local or Traditional variety		
Season	Qty. (kg)	Price	Season	Qty. (kg)	Price
i. Major			i. Major		
ii. Minor			ii. Minor		

B3. Did you apply fertilizer at any point in the production season? 1=Yes [] 0 = No []

B3.1. If yes, what type of fertilizer did you apply? 0 = Inorganic [] 1 = Organic [] 2 = Both []

B3.2. Please complete this table on fertilizer use if applicable

Table 4: Fertilizer usage: 2017

Major Season				Minor Season			
Fertilizer	Qty.(kg)	Price(GHC)	ToA	Fertilizer	Qty.(kg)	Price(GHC)	ToA
23/10/10				23/10/10			
23/10/5				23/10/5			
25/10/5				25/10/5			
Urea				Urea			
S. Amonia				S. Amonia			
Others				Others			
i.				i.			
ii.				ii.			

23/10/10..... Are NPK fertilizers; ToA = Time of application; 1bag =kg

B4. Did you apply any form of agrochemical? 1 = Yes [] 0 = No []

B4.1. Please complete the table on agrochemical use if applicable.

Table 5: Agrochemical usage 2017

Major Season				Minor Season			
Agrochem.	Qty.(Lt)	Price(GHC)	To A	Agrochem.	Qty.(Lt)	Price(GHC)	To A
Glyphosate				Glyphosate			
2,4-D				2,4-D			
Roundup				Roundup			
Nicoghan				Nicoghan			
Others				Others			
i.				i.			
ii.				ii.			

ToA = Time of application;

B5. Is maize farming your major occupation? 1 = Yes [] 0 = No []

B5.1. If no please indicate your major occupation. 1 = Trading [] 2 = Salary worker []
3 = Artisan [] 4 = Other farming activity [] 5 = Other(specify) []

B5.2. How did you acquire your land for farming? 1 = Purchase [] 2 = Rented/Lease []
3 = Family land [] 4 = Borrowed []

B5.3. How much does an acre of land cost if it was rented? GHC..... per acre.

B6. Do you belong to an FBO? 1 = Yes [] 0 = No []

B6.1. If yes, do you receive any support/assistance from the group and in what form?

1=Book-keeping training [] 2=Agronomic practices [] 3=Cash/Credit support []
4=Credit management [] 5=Others(Specify).....

B7. Did you have access to extension service? 1 = Yes [] 0 = No []

B7.1. If yes, please indicate the number of contacts in the production seasons.

- a. Major season (number of times).....
- b. Minor season (number of times).....

B8. Did you receive any form of credit? 1 = Yes [] 0 = No []

B8.1. If yes, please indicate source, form, amount and interest charges in the table below.

Table 6: Access to Credit 2017

Source	Form		Interest charges
	Cash (GHC)	In-kind	
Formal Bank			
Family/Friend			
Money lenders			
Others			

B9. Indicate the kind of farm implements employed on your farm. 1=simple farm tools (e.g. cutlass, hoe, knapsack sprayer etc) [] 2=Tractor [] 3=Plough [] 4=Ridge [] 5=Combine harvester [] 6=Sheller [] 7=Seeder [] 8=Others(Specify)

SECTION C: Labour requirements for the production season

C1. What is the major source of labour employed on our farm? Please tick appropriately

Table 7: Source of Labour 2017

Family labour				Hired labour			
Adults		Children		Adults		Children	
Male	Female	Male	Female	Male	Female	Male	Female

Adults: People > 18yrs

Children: People <18yrs

C2a. Labour requirements by production activities

C2b. How many days do you work on your farm in a week?

- a. Major season.....
- b. Minor season.....

C2c. How many weeks are in each season?

- a. Major season.....

b. Minor season.....

Table 8a: Sources of labour (Major season) 2017

Family labour					Hired labour				
Role of worker	Number of workers employed		Hours per day	TC/day (GHC)	Role of worker	Number of workers employed		Hours per day	TC/day (GHC)
	Males	Females				Males	Females		
i. Land Prep.					i.Land Prep.				
ii. Weeding					ii. Weeding				
iii. Fert. Appl.					iii. Fert. Appl.				
iv. Herb. Appl.					iv. Herb. Appl.				
v. Insect. Appl.					v. Insect. Appl.				
vi. Planting					vi. Planting				
vii. Harvesting					vii. Harvesting				
viii. Dehusking					viii. Dehusking				
ix. Bagging					ix. Bagging				

Notes: Prep=Preparation, Fert=Fertilizer, Appl=Application, Insect=Insecticide, Herb=Herbicide, TC=Total Cost

Table 8b: Sources of Labour (Minor Season) 2017

Family labour					Hired labour				
Role of worker	Number of workers employed		Hours per day	TC/day (GHC)	Role of worker	Number of workers employed		Hours per day	TC/day (GHC)
	Males	Females				Males	Females		
i. Land Prep.					i. Land Prep.				
ii. Weeding					ii. Weeding				
iii. Fert. Appl.					iii. Fert. Appl.				
ii. Herb. Appl.					iv. Herb. Appl.				
v. Insect. Appl.					v. Insect. Appl.				
vi. Planting					vi. Planting				
vii. Harvesting					vii. Harvesting				
viii. Dehusking					viii. Dehusking				
ix. Bagging					ix. Bagging				

C3. Questions on Assets. Capital assets of production

Table 9: Capital assets 2017

Item	Cost over production period (GHC)			
Transport				
Mechanization (Tractor, Combine harvester, Sheller, Seeder)				
Fuel				
Hired Machines				
Others (Specify)				
	Quantity	Purchase date	Cost Prices (GHC)	Lifespan (years)
Hoe				
Cutlass				
Knapsack sp.				

Others (Specify)				
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SECTION D: Information on output, consumption, sales, storage, and spoilage.

D1. Please fill out the table below

Table 10: Output, Consumption, Sales, Storage, and Spoilage 2017

Season	Output(kg)	Qty. sold (GHC)		Consumption/Gift(kg)	Storage and spoilage(kg)	
		Amount	Price/unit		Storage	Spoilage
Major						
Minor						

1bag =kg

D2. Please do you have a ready market for your marketable surplus? 1= Yes [] 0= No []

D2.1. If yes how far is the market from your farm?kilometers(km)

D2.2. If no, why?
.....

D3. Please indicate in kilometers the distance from your house to your farm
.....

D4. Do you have easy access to transportation? 1=Yes [] 0=No []

D4.1 How much did it cost to produce in the production year under review on the average?

- a. Major season (GHC).....
- b. Minor season (GHC).....

D5. Do you have access to storage facilities? 1=Yes [] 0=No []

SECTION E: Farm Constraints

E1. Kindly use the scale below to rank the under listed constraints faced in maize production

Scale:

1 -most pressing constraint	→	11 -least pressing constraint
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Table 11: Constraints 2017

Constraints	Ranks (1-11)
High cost of production	
Land acquisition and land tenure problems	
Accessibility to recommended fertilizers	
Accessibility to improved maize varieties	
Accessibility to recommended insecticide and herbicide	
Diseases and pest attacks on farm and during storage	
Access to credit	
High interest rates	
Storage problems and spoilage	
Challenges of ready market for marketable surplus	
Transportation to and from farms through to market centers	