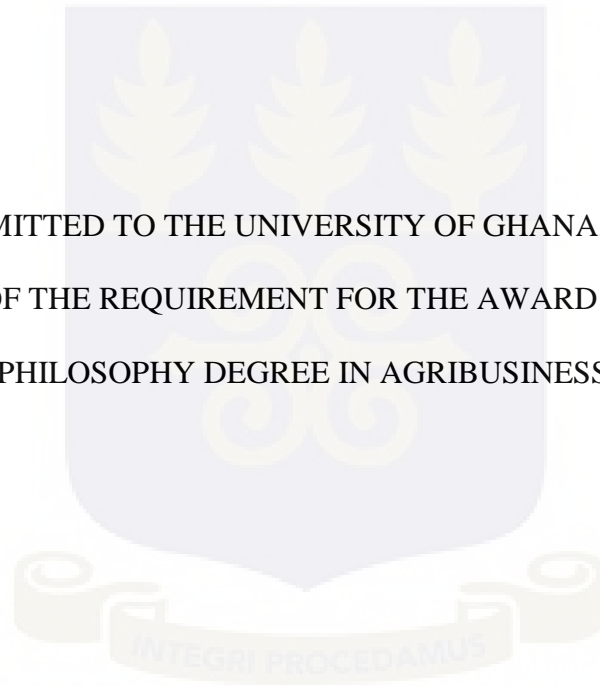


AGGLOMERATION EXTERNALITIES, PRODUCTIVITY AND TECHNICAL EFFICIENCY
OF SOYBEAN FARMS IN THE UPPER EAST AND UPPER WEST REGIONS OF GHANA

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON, IN PARTIAL
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DEPARTMENT OF AGRICULTURAL ECONOMICS AND AGRIBUSINESS, COLLEGE OF
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JULY, 2017

DECLARATION

I, ANTWI DAVID EZEKIEL, author of this thesis titled “AGGLOMERATION EXTERNALITIES, PRODUCTIVITY AND TECHNICAL EFFICIENCY OF SOYBEAN FARMS IN THE UPPER EAST AND UPPER WEST REGIONS OF GHANA”, do hereby declare that with the exception of references to past and present literature which were duly cited, the entire research leading to this thesis was carried out by me in the Department of Agricultural Economics and Agribusiness of the College of Basic and Applied Sciences, University of Ghana, Legon, from August 2016 to July 2017. This work has never been presented either in whole or in part for the award of any degree in this University or elsewhere.

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(Co-Supervisor)

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Date

DEDICATION

This thesis is dedicated to my parents, Apostle and Mrs. Joseph Kwabena Antwi, to my siblings, Joel, Esther, Paul, Philip, Betty, Christiana and to Yvonne Arden.



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I acknowledge God for the gift of life, for good health, knowledge and wisdom. I also extend my heartfelt gratitude to my supervisor Dr. Edward Ebo Onumah for his invaluable pieces of advice, correction, encouragement and input. I am very grateful for the many hours of his time that were dedicated to my work, and for helping to mold my thesis into what it has become. This thesis would never have taken off without Dr. Edward Ebo Onumah and I am very thankful. I am also indebted to my supervisor Professor Ramatu Al-Hassan for the time spent to read through my work, and the input made, without which my work would not have been complete. This thesis would not have been possible without her invaluable input.

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ABSTRACT

The study set out to identify agglomeration externalities in Ghana's soybean sector and to assess soybean output elasticities with respect to input-use. The study also analyzed the technical efficiency levels in the soybean sector and the effect of agglomeration externalities on productivity and technical efficiency of soybean farms. The study identifies some components of agglomeration externalities across the soybean sector and defines agglomeration externalities by two indexes; industry size captured by whether the farmers belong to Farmer Associations (FA) and if they do, what their Farm Densities (FD) are, measured by the number of smallholder farms per square kilometre that the individual farms belong to. A stochastic frontier model with the agglomeration indexes FA and FD and a technical efficiency model are specified to ascertain the effects of agglomeration and its externalities on the production frontier and efficiency of the soybean farms. The estimation of the frontier model is carried out on data collected from 393 soybean farms in the Upper East and Upper West Regions of Ghana. Also, 193 of the 393 farmers belong to farmer associations while the remaining 200 do not. The Ox-SFAMB version 3.40 was used to estimate the parameters. Hypotheses tests carried out using Log-likelihood ratio estimates indicate that the translog stochastic production model is the best fit for the data. The results show that for the production frontier, FA and FD are seen to have a significantly positive relationship with productivity. The coefficients of FA and FD are 1.02 and 0.03. The positive relationship between productivity and farm density suggests the presence of positive congestion externalities. FD has a positive influence on efficiency but FA was found to have negative implications on the technical efficiency of soybean farms. The results of the Maximum-Likelihood Estimates of the stochastic frontier model show that a percentage increase in seed, capital, labour and fertilizer, respectively, will increase the soybean production frontier by 0.14, 0.14, 0.28 and 0.41 percent. The soybean sector exhibits diminishing returns to scale of 0.98 percent increase in output with one percent increase in all input with the mean technical efficiency index of the sector estimated at 0.52. Age and gender have a negative relationship with efficiency. This indicates that younger farmers are more efficient than their older counterparts and female farmers are more efficient than male farmers. Increase in frequency of farmer-extension agent interactions also leads to increase in the efficiency of the farmers. The findings of the study confirm that FA and FD have significant influence on productivity and technical efficiency of soybean farms. The implications of these results are that there is the need for government and stakeholders to help improve productivity and efficiency in the soybean sector by helping farmers to better access positive agglomeration externalities. Government should put mechanisms in place to ensure easy access of farmers to factor inputs such as seed and fertilizer. Extension officers must interact more with soybean farmers and introduce high yielding seeds to farmers to enable them cut down on costs of production. Field trials and workshops should be organized to teach farmers better farming practices and motivate farmers to adopt new farming technologies.

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ACRONYMS AND ABBREVIATIONS

AVCMP	Agricultural Value Chain Mentorship Project
CAPECS	Centre for the Alleviation of Poverty, the Environment and Child Support
CARD	Community Aid for Rural Development
CSIR	Council for Scientific and Industrial Research
FA	Farmer Association
FBO	Farmer Based Organization
FD	Farm Density
GAP	Good Agricultural Practice
GLSS	Ghana Living Standards Survey
GROW	Greater Rural Opportunities for Women
GSS	Ghana Statistical Service
IPM	Integrated Pest Management
ISFM	Integrated Soil Fertility Management
KFP	Key Facilitating Partners
L-R	Log-likelihood Ratio
MEDA	Mennonite Economic Development Associates
MLE	Maximum Likelihood Estimate
MoFA	Ministry of Food and Agriculture
SADA	Savannah Accelerated Development Authority
SRID	Statistics, Research and Information Directorate
TUDRIDEP	Tumu Deanery Rural Integrated Development Programme
USAID	United States Agency for International Development

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The importance and relevance of soybeans to Ghana cannot be overemphasized, and this has led to the promotion of soybean production through the concerted efforts of some stakeholders like the CSIR (Council for Scientific and Industrial Research), MoFA (Ministry of Food and Agriculture) and other development partners. Especially due to its income-increasing potential and nutritional value (Mbanya, 2011), it has become economically and nutritionally prudent to ensure the sustainability of soybean production in Ghana. Also, soybean has some medicinal properties and is especially potent for the prevention and/or treatment of cardiovascular diseases (Sanful and Darko, 2010).

Soybean has over the years become an important source of foreign exchange for Ghana (Aoyagi and Shurtleff, 2007) with exports being mostly to the United Kingdom. In recent times, the local industry in Ghana has also become one of the main focuses of soybean production, soybean being considered considerably as a nutritional supplement and also as playing a significant role in ensuring food security especially for farmer households (Shannon *et al.*, 1995). About 150,000 MT of soybean is demanded in Ghana every year, with the largest proportion of this quantity going into soybean oil and soybean meal production (USAID, 2012). The advantages of soybean over other leguminous crops include comparatively low susceptibility to pest and disease attacks and the ability to store the grains easily (Etwire *et al.*, 2013) making it easily cultivable by smallholder farmers with very limited resources.

In 2012, the Statistics, Research and Information Directorate (SRID) of MoFA indicated that more than two-thirds of the country's soybean output is from the northern part of Ghana. This fact has

necessitated and facilitated the establishment of certain *units* by some stakeholders and NGOs in the north, usually referred to as Key Facilitating Partners (KFP), to fund and streamline the production of soybean and other crops in the region.

Mennonite Economic Development Associates (MEDA), as part of its mandate to create business solutions to poverty (MEDA, 2017), partners some local organizations/initiatives and these include CARD, PRONET, PRUDA, CAPECS and TUDRIDEP. These initiatives also offer aid to women farmers through the GROW (Greater Rural Opportunities for Women) initiative to enable them increase their productivity. These initiatives seek to improve and increase the production of some main crops in the northern part of Ghana, including soybean.

Technical efficiency and productivity studies abound in agriculture to enable the assessment of the effectiveness and efficiency of input-use and also measure production and efficiency levels against an optimum production frontier of 1 (100%). Through development projects such as the Agricultural Value Chain Mentorship Project (AVCMP), the CSIR has extended some soybean technologies to the Northern part of Ghana to help improve the efficiency and also the productivity of the sector (Etwire *et al.*, 2013). These technologies include and/or are embodied in GAPs, use of certified seeds, Integrated Soil Fertility Management (ISFM), Integrated Pest Management (IPM), amongst others (Etwire *et al.*, 2013). In spite of these technology interventions, in 2011, MoFA reported that the average soybean yields of farmers was about 1.5 MT/Ha which is 35 percent below predicted achievable yields of 2.3 MT/Ha (MoFA, 2011).

Even in spite of the numerous efficiency and productivity studies conducted for a diverse list of crops, there still seems to be very little work done and therefore very little information on the productivity and also the profitability of the soybean sector (Etwire *et al.*, 2013; Mohammed *et al.*, 2016). Low productivity in the sector could also be attributed to a lack of adequate resources for

improved technology. Efficiency studies however could help with recommendations to improve efficient and effective utilization of available input resources to improve productivity and that is why this paper seeks to investigate both parameters.

Empirical studies on agglomeration externalities have been conducted over the years to establish a link between the size of an industry and the externalities that arise among the firms that belong to these industries. In carrying out these studies, there has been put forward a hypothesis, according to Battese and Tveteras (2006), that there exists a positive relationship between the size of an industry (industry agglomeration) and the externalities that arise among firms belonging to the industry and this positive relationship may lead to increase in productivity. These externalities could occur between competing firms, between a firm and its customers or even a firm and its vendors (Battese and Tveteras, 2006). This study gives results on empirical analysis conducted on a primary production sector for small-holder soybean farmers. This is with the view that the soybean sector can in so many ways be likened to and treated as an industry due to the advent of technology, labour specialization and indivisibilities that are associated with physical capital and labour (Puga, 2009).

The concept of agglomeration externalities embodies spillover information, among other factors, that may lead to knowledge pertaining to inputs that are used by farmers, distribution routes, processing methods, marketing strategies, and production methods. These externalities may arise from soybean farmers (especially small-holder farmers) forming and/or belonging to groups/associations (FA), and proximity of farms to each other. The externalities may also arise from Farm Density (FD), measured by the number of farms per square kilometre. Increased levels of localized knowledge spillovers could lead to fewer errors in decision-making and this could lead to a more efficient and productive soybean farming system.

These agglomerations may be necessitated by the uneven distribution of local endowments, either natural or man-made, such as institutions and infrastructure, and the spatial relationship among economic structures (Maciente, 2013; Henderson *et al.*, 2001). However very few technical efficiency studies consider agglomeration externalities, as is the case in Ghana.

Following the study conducted by Battese and Tveteras (2006), this study looks at a three-pronged approach to reaching its set-out objectives. First of all, measurements of agglomeration externalities are carried out on farm-level data rather than on aggregate industry data. Aggregation biases that are associated with internal returns to scale (IRS) and assumptions of cross-industry/cross-sector homogeneity for input variables included in the production frontier are avoided. By extension therefore, estimates of external returns to scale are only slightly influenced or not at all (Burnside, 1996). Secondly, there is a separation of analysis of effects on the production frontier and on technical efficiency and not estimates on average production functions. Thirdly, the study provides evidence for a primary production sector; the soybean farming sector. In effect, what this study seeks to do is to establish the effects of externalities that arise from agglomerations on the technical efficiency and productivity of soybean farms in northern Ghana with concentration on small-holder farmers.

1.2 The Soybean Sector

Soybean is an edible crop with high value and profitability (Thoenes, 2007) with very high economic viability stemming from the commercial importance and utilization of both its meal and oil. The economic benefits derived from the sub-products of soybean, the meal and oil, account respectively for two thirds and a third of soy's economic value worldwide. It has relevance both domestically and globally, serving as a vital income-earning economic activity and a source of nutrition.

1.2.1 The Global Soybean Sector

Four countries are known globally to spearhead the production of soybean; USA, Argentina, Brazil and China. These countries account for almost 90 percent of global output (Thoenes, 2007). Soybean accounts for over 60 percent of the world's vegetable and animal meal production and is used extensively in the manufacture of feed meals and concentrates. According to Thoenes (2007), it is the second most important vegetable oil, second only to palm oil.

Soy production in 2016 reached 313.06 million MT with the USA, Brazil and Argentina contributing about 89 percent of this quantity (USDA, 2017). There has therefore been an increase of about 19 percent within the last four years from production levels of about 253 million MT in 2012, with Brazil, USA and Argentina contributing to about 76 percent of this quantity (FAO, 2013). Projections for soybean production are still rife with positive expectations of about 23 percent expansion in the sector over the next 10 years as there continues to be breakthroughs in soybean varieties and technology of production leading to a wider and more varied usage of soybean.

Africa and other parts of Asia (excluding China) have seen the lowest production levels of soybean (FAO, 2013) but future projections show that production levels in these regions are to go up significantly as interactions between the highest producers and these regions become more effective.

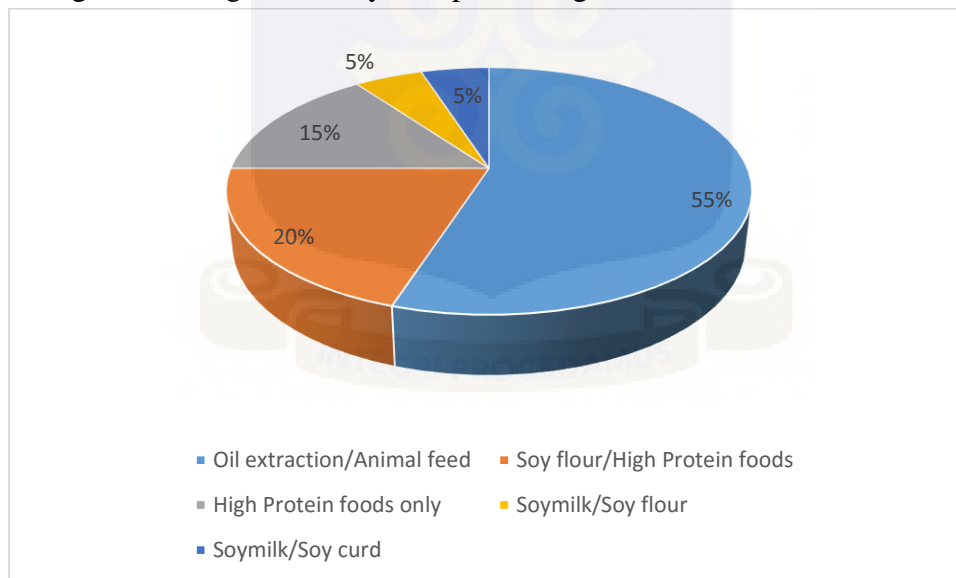
1.2.2 Ghana's Soybean Sector

The initial primary purpose for soybean in Ghana according to Aoyagi and Shurtleff (2007) was for exportation as a cash crop and to serve as a nutritional supplement for farmers and their households. These exports were mostly to the United Kingdom. The focus of soybean production, over the years, has shifted to one that focuses largely on supplying local industry. The mentality

that governed Africa’s perception about soybean has also gradually moved from it being only suitable for industrial processing and livestock feed (Shannon *et al.*, 1995) to the major role it can play in ensuring food security.

There is a clear dichotomy between large-scale and small/micro-scale soybean production and processing in Ghana (Mohammed *et al.*, 2016). According to Plahar (2006), large-scale processing can be categorized into oil extraction and animal feed, soy flour and high protein foods, high protein foods only, soymilk and soy flour, and soy curd (Figure 1.1). The large-scale soybean processing sector employs relatively more sophisticated equipment and better technology in the processing of soybean which is in contrast to more traditional and primitive equipment and methods employed in the small-scale (micro/household) sector.

Figure 1.1: Categories of large-scale soybean processing in Ghana



Source: Plahar, 2006.

According to the United States Agency for International Development (USAID) (2012), one of the main soybean sector drivers in Ghana is the use of soybean meal in the rations of birds in the local egg industry. About 75% of the 150,000 MT demanded of soybean every year feeds the local egg

industry, the bulk of this amount going into the production of soybean oil and soybean meal (USAID, 2012). Table 1.1 shows a summary of the soybean market in Ghana.

Soybean cake, which is used in layer feed rations, takes up the bulk of the end product and use of soybean produced in Ghana. The rest of the produce is used for soybean oil for industry and also for human consumption, according to USAID (2012).

Table 1.1: Ghana Soybean Market

Product	Total Market (Metric Tonnes)	Import Supply – (% of market share met by imports)	Wholesale and retail prices (\$/MT)
Soybean cake	Between 75,000 and 100,000 MT	Between 48% and 61%	\$1,060-\$1,200/MT at 2011 peak
Soybean oil	About 20,000 MT	70%	\$1,733/MT
Food processing (human)	<1,000 MT	0%	-
Producer Household retention	About 20,000 MT	N/A	N/A
Average (total)	150,000 MT	About 50%	-

Source: USAID, 2012.

Due to recent donor focus on soybean production, in the face of the recent tight global demand for and supply of soybean, there has been significant growth in area planted of soybean. This is also driven by the upsurge in demand for vegetable oil and its products as well as for poultry products. About 76,000 hectares of soybean was recorded in 2010 alone in Ghana, with more than half of this area in the Northern Region (MoFA, 2010) (Table 1.2). Total area cultivated for 2010 reached about 90,000 hectares with average yields of 1.2 MT/Ha.

The northern parts of the Brong-Ahafo and Volta Regions, and the three northern regions of Ghana (SADA belt/region) are among the highest potential soybean production areas in the country. Table

1.2 shows that the Northern Region of Ghana recorded the highest area planted of soybean of 49,950 hectares, followed by the Upper West Region with 14,970 hectares. Among the three Northern regions, the Upper East Region recorded the least area of 6,940 hectares.

The northern part of the Volta Region of Ghana, which is to the eastern border of Ghana, recorded an average area planted of soybean of 4,360 hectares (USAID, 2012) which makes it the fourth highest cultivator of soybean by farm area in Ghana (Table 1.2).

Table 1.2: Ghana Soybean Production

Region	Area Planted (Hectares)
Brong-Ahafo	0
Northern	49,950
Upper West	14,970
Upper East	6,940
Volta	4,360
Total SADA	76,000
Ghana Total	76,000
Average Yield	1.2 MT/Ha
Total Production	Approximately 90,000

Source: USAID, 2012.

In spite of the obvious strides to making soybean production a priority through the interventions of some initiatives of Development Partners and NGOs, there still is a demand gap that exists due to inadequate soybean production and/or processing. According to the Ministry of Food and Agriculture (MoFA), Ghana has recorded production shortfalls in the soybean sector that has required augmenting through importation. The ministry has stated that the country continues to produce short of its production potential (Mohammed *et al.*, 2016) and this situation can worsen if

steps are not taken to make the growth of the soybean sector more sustainable. This study looks at one of the ways in which sustainable growth can be attained, which is by increasing the efficiency and productivity of soybean farmers and farms. The study investigates the creation of agglomeration economies and what effects the ensuing agglomeration externalities have on efficiency and productivity.

1.3 Problem Statement

Studies on technical efficiency and productivity encompass the maxim of producing more with less. This is particularly important for a developing society like Ghana that has comparatively less resources and high poverty ratings among its farmers. In the face of scarce input resources, farmers would want to maximize input-use to enhance productivity through efficiency.

Efficiency studies are necessary as they address the effectiveness of input combinations in order to produce optimum output levels without necessarily increasing the levels of input used for the same quantum of economic activity. Some studies have been carried out on efficiency and productivity for some common staple crops in Ghana. There however seems to be very scanty information pertaining to the efficiency and productivity of soybean farming (Mohammed *et al.*, 2016). These studies are relevant to the sector as the estimations may give indications as to the efficient utilization of available input factors to optimize production.

Most conventional studies do not include the subject of agglomerations, the externalities that arise from them and the implications on productivity and efficiency. Efficiency studies have not comprehensively identified these agglomeration externalities especially in the soybean sector, and so have not been able to estimate their effects on productivity and efficiency.

Researchers may go a step further by considering agglomeration externalities and their effects in their efficiency studies especially since FBOs are a commonality in Ghana's farming sector. For the soybean sector, this will create some knowledge about the effects of farmer groupings on their efficiency and productivity, and enable empirical measurements of the parameters that arise from these agglomeration externalities (Battese and Tveteras, 2006). This will better fine-tune the management of soybean farming. The non-inclusion of agglomeration externalities in most efficiency studies therefore creates a gap in research and literature.

The externalities that arise from agglomeration could be both positive and negative. Some of the negative externalities could be an increase in the incidence of pests or a spread of crop diseases among farms due to their proximity to each other or due to harmful information that is spread among farmers because they belong to the same agglomerates. There are also, however, positive externalities that may arise from these groupings. Some of these are increased levels of localized knowledge that may lead to productivity gains and translate into higher returns that may in turn attract a lot more players and actors into the farming sector. This may lead to the production of further externalities in an autonomous and self-reinforcing cycle (Markusen, 1996; Rosenthal and Strange, 2001).

It would therefore be in the interest of researchers and stakeholders to be in the know about measurements pertaining to these parameters, to better harness available resources to ensure that the positive externalities are maximized as the negatives are minimized (Puga, 2009). Unfortunately, due to the absence of such studies, especially for the soybean sector in Ghana, this information is either absent or inadequate and as such we are unable to capitalize on the situation and harness it to our advantage.

Also, due to the lack of resources, especially for improved technology, productivity in the soybean sector is low (Etwire *et al.*, 2013). There is inadequate work done on productivity and efficiency in Ghana's soybean sector and this is problematic considering that efficiency studies could inform policy makers, farmers, NGOs, the government and other stakeholders on effective ways of utilizing inputs efficiently to improve productivity and to alleviate poverty.

This study therefore seeks to estimate the effects of agglomeration externalities on the efficiency of input-use and the production frontier in the soybean sector in Ghana and by virtue of that, among other things, bridge the existing literature and research gap.

1.4 Research Questions

There is an apparent potential for higher efficiency and productivity in the soybean sector, and this is evidenced by the reports of the efficiency studies carried out in the sector. By incorporating the element of measuring and estimating agglomeration externalities in efficiency studies, a better and clearer understanding of the effects of farmer groupings and farm/farmer proximities may inform policy on better ways of improving technical efficiency and productivity and reducing unnecessary losses and poverty on farms and among farmers respectively. This has led the study to ask the following research questions:

1. What are the agglomeration externalities in Ghana's soybean farming sector?
2. What are the output elasticities with respect to input-use?
3. What are the technical efficiency levels in the soybean sector?
4. What are the effects of agglomeration externalities on the productivity and efficiency of soybean farms?

1.5 Objectives of the Study

The main objective of the study is to determine the agglomeration externalities, productivity and technical efficiency of soybean farms in the Upper East and Upper West Regions of Ghana. The specific objectives of the study are to;

1. Identify the agglomeration externalities in the soybean sector
2. Estimate output elasticities with respect to input-use
3. Determine the technical efficiency levels in the soybean sector, and
4. Analyze the effect of agglomeration externalities on productivity and efficiency of soybean farms

1.6 Relevance of the Study

Agglomeration studies have not been sufficiently explored in farm studies, especially in the case of Ghana, to determine how and to what extent agglomeration can affect the productivity and technical efficiency of farms. This is particularly so for the soybean industry. In an era where industry agglomeration and co-agglomeration is being explored to harness information on the effects that they have on efficiency and productivity, it is only prudent that such studies are undertaken.

There are some externalities that arise from agglomerations and this study identifies them and assesses them. The study also estimates the effect of these externalities on efficiency and on the production frontier. The quest to establish that assessing these externalities is relevant and that efficiency studies are incomplete without factoring in the effects of these externalities justifies this study. This study tries to fill existing gaps in the literature on technical efficiency and productivity studies especially in the soybean farming sector. To add to literature and inform policy, this study

also sets out to estimate the effect of input-use on the production frontier and also to estimate the technical efficiency levels in the soybean sector.

Agglomeration externalities is captured using two indexes, FA and FD, which assess industry size and the number of farms located within a predefined area respectively. By so doing, the research tries to ascertain the effects that belonging to farmer groups have on the efficiency and productivity of the farmers and their farms. FD also tries to capture the positive and negative externalities that may arise from proximity of soybean farms to each other, and in so doing assess the relationship between farm density, technical efficiency and the production frontier.

This study therefore tries to fill the gaps in efficiency studies that do not include agglomeration externalities in their analysis. The study suggests some recommendations based on findings that show that indeed, agglomeration externalities can take a toll on the efficiency with which soybean farmers combine input for production and the subsequent output of their farms.

1.7 Organization of Thesis

The thesis is structured and broken down into five chapters. Following chapter one which gives a brief introduction and background to the study and outlines the research questions and objectives, the problem statement and justification of the study, chapter two presents a review of literature relevant to the research. Chapter three describes into detail the methodology of the study and the methods that were employed in the analysis of the survey data collected from the field. The results and discussion are presented in the fourth chapter. Chapter five outlines the summary, conclusion, and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter comprehensively reviews literature pertaining to the soybean sector in Ghana and addresses issues related to technical efficiency, productivity and agglomeration. It also identifies relevant issues that are of concern to this study that have been investigated by other authors and the linkages between their work and this one. This section also reviews the various aspects of agglomeration and its externalities in general and then vis-à-vis the situation in Ghana. It addresses issues of efficiency and productivity and what effect agglomeration externalities have on them, identifies agglomeration externalities that may exist in the soybean sector and examines issues pertaining to output elasticity estimations with respect to input-use.

2.2 Agglomeration Economies

Agglomerations, and the externalities thereof, have become an important feature of the economic landscape. Agglomerations have become necessary due to an uneven distribution of resources, both natural and artificial. These groupings/agglomerations have spillover effects referred to as externalities and these externalities arise from agglomerations and have a very important significance for industries. Agglomeration externalities can arise from proximity of firms/farms to each other and/or to customers. The advantages gained from these externalities have given firms some competitive edge by expanding production possibilities beyond erstwhile restrictions that were imposed by a number of exogenous factors inimical to high productivity (Maciente, 2013).

As pioneered by Marshall (1920) and developed by other authors on the subject, such as Ellison, Glaeser and Kerr (2010), in the Marshallian view, agglomeration reduces transportation cost, cost of moving goods and cost of transfer of ideas. By virtue of proximity therefore, firms would either

locate near suppliers to save on shipping costs, or would locate to stay close to a specialized labour pool to facilitate access to appropriate labour as and when needed, and also so they can benefit from local knowledge spillovers (Maciente, 2013).

Glaeser (2010) describes economies of agglomeration as those benefits that arise from people and firms locating and/or relocating in close proximity to one another. Puga (2009) says that agglomeration economies arise when there is a situation of aggregation of firms and workers in a given environment as opposed to disaggregation especially in location. Following Marshall's observations (Marshall, 1920) about agglomeration economies, many other authors have classified agglomeration economies as either being direct or indirect, either expressed through the market system or not (Scitovsky, 1954), either informal or institutionalized (Porter, 2000) and either internal or external to the firm (Parr, 2002a; 2002b). The existence of agglomeration economies is evidenced by the concentration of firms, people and industries and is further defined by the consequent interactions within these groupings and how they tell on certain parameters, such as cost, which inevitably affect the economy.

2.2.1 Sources of Agglomeration Economies

The concept of agglomeration revolves around clustering, and the objective of any researcher on the subject is to ascertain and understand the mechanisms that make this clustering productive and profitable. For instance, Krugman (1991) introduces the classic model of agglomeration that emphasizes agglomeration benefits that arise from a reduction in transporting goods over space. As such, the merit derived from this agglomeration (that is supplier locating closer to the customer) is a reduction in transportation cost (Glaeser, 2010).

The sources of agglomeration could therefore arise from the cost of moving people (Glaeser, 2010). Krugman (1991) demonstrates how it would be more economically sound and productive

for an input supplier to locate his business close to a final goods producer and thus save on cost of shipping of input (goods). There is however the element of moving people across space, where the value of time is considered in forming agglomerates. This encompasses people travelling across space to buy goods and ensure labour matching, where it is easier and cheaper to locate and match labourer and employer, when these clusters are effective. Agglomeration results are more impactful when the sectors that implement them are heterogeneous, to avoid correlation of shocks, but at the same time are similar enough so as to allow for movement of workers across the different firms (Glaeser, 2010; Overman and Puga, 2010).

Aside labour pooling, another source of agglomeration economies is knowledge spillovers (Jacobs, 1969; Marshall, 1920) that come about as a result of a faster flow of ideas and information between people and firms due to proximity. Chinitz (1961) argues that a business community with a lot of smaller businesses and firms is more likely to flourish in comparison to one that has a few large firms. This, he says, is due to the fact that there is a more vibrant intellectual linkage in the former scenario than in the latter.

Puga (2009) outlines six main sources of agglomeration economies; firms sharing facilities, firms sharing suppliers, firms sharing gains from individual specialization, firms sharing a labour pool, better matching of employees and employers, and learning within firms. This is made possible by the large size of the market where these firms interact. Larger markets allow for better efficiency in the sharing of local facilities, amenities and infrastructure. It also creates a conducive environment for sharing of workers or labour with similar skill and intermediate suppliers of input (Puga, 2009).

Large agglomerates also facilitate linkages between business partners, suppliers and buyers, labourers and employers, and so on. There is also the likelihood of a high incidence of learning,

or knowledge-sharing, resulting in the adoption of certain technologies or practices. These end up creating agglomeration economies that could have positive implications for the sector, for agriculture and for the economy as a whole (Puga, 2009).

2.2.2 Classification of Agglomeration Economies

Agglomeration economies could be categorized into two broad groups; economies that are external and those that are internal to the firm (Parr, 2002a; 2002b). There is a strong linkage and parallelism between the two classifications. Parr (2002a) further classifies internal and external agglomeration economies into three other categories, based on their economic rationale (Maciente, 2013) and these are by *scale*, *scope* and *complexity* (Parr, 2002a; 2002b) (Table 2.1).

Internal economies of scale are seen to occur when large localized outputs within a production unit tend to reduce costs related to production, and whenever the production costs of more than one product within a firm is less than production costs incurred by separate firms (Maciente, 2013), or when production of multiple outputs translates into a more efficient combination of inputs, then there is Economies of scope or of lateral integration (Parr. 2002a). There is also vertical integration of local production which involves the agglomeration of the different stages of production in one firm, and this brings about internal economies of complexity.

External economies however occur as a result of agglomeration through location, where the location of one firm can have positive implications and effects, such as minimizing production cost, on other privately owned and operated firms in the locality. *Marshall-Arrow-Romer* economies, better known as External economies of scale or localization economies, refers to and is made up of all cost savings to a firm that is attributed to the local scale of its own industry (Maciente, 2013). Knowledge spillovers lead to horizontal integration within firms and this results in localization economies.

Table 2.2: Classification of agglomeration economies

	Internal to the firm	External to the firm
Scale	Horizontal integration	Localization economies
Scope	Lateral integration	Urbanization economies
Complexity	Vertical integration	Activity-complex economies

Source: Parr, 2002a.

Diseconomies of scale could also occur where cost disadvantages arise due to increase in per-unit costs of inputs. This could be as a result of increase in firm size or output which results in production of goods at increased costs. This results in a negative externality that arises from agglomeration.

Firms that belong to different industries can also co-locate and this can result in External economies of scope (Beaudry and Schiffauerova, 2009; Fujita and Thisse, 2002) and this is closely related to or present among firms located in markets with specialized units (Jacobs, 1969). There are also External economies of complexity which operate in a vertically integrated process and occur as a result of co-location of firms belonging to a specific production chain; industries linked through direct or indirect trade linkages (Parr, 2002b). These economies may become internal agglomeration economies if the firms merge into one or are subsequently owned by one single firm.

The different classifications give a better understanding of how they act independently but can also complement each other by incentivizing agglomeration and co-agglomeration of firms and industries respectively (Viner, 1932). The creation of agglomeration economies leads to externalities that can either be classified as positive or negative depending on the efficiency and effectiveness of the economies.

2.3 Agglomeration Externalities and Their Implications

Agglomeration externalities which arise from the presence of local markets specializing in one product/service or another, and also due to the presence of intermediate products (Larue and Latruffe, 2008), are cited by Duranton and Puga (2004) as having positive implications such as knowledge spillovers, demand-matching, labour supply, and input-sharing.

Agglomeration externalities have a very vital function in the creation of economic agglomerations (Fujita and Thisse, 2002; Marshall, 1920). Unlike *concentration*, which describes different economic phenomena, agglomeration is more definitive and less ambiguous in describing clusters that are encouraged by the externalities that arise from them. Agglomeration externalities could have negative influences on the members of the clusters, and these could include spread of plant disease, water shortage problems among farms, widespread effects of bad farming practices and so on. Fujita and Thisse (2002) however outline four positive agglomeration externalities and conditions that are relevant for the formation of clusters:

1. Availability of a larger labour pool or force from which employers can recruit (made possible by clustering).
2. Availability and facilitation of effective information-sharing (made possible by clustering and proximity of firms to each other).
3. Demand-matching (leading to specialization).
4. Sharing of resources.

These merits come about especially as a result of proximity and a subsequent increase in the propensity of group members to interact with each other. Agglomeration externalities tend to give members of clusters a competitive edge over non-members. For instance, in agriculture, farmers are able to access tools and equipment that were erstwhile unavailable to them, from neighbouring

farms, at no or very low costs. The Marshallian externalities concept captures the idea that agglomeration externalities arise from a snowball effect where firms would want to congregate with the main aim and purpose of benefitting from a large diversity of economic activities and a high degree of product specialization. According to Matsuyama (1995) agglomeration externalities result in increasing returns to scale and provides members with competitive advantage in the economy.

There are two main categories in which to view agglomeration externalities. Scitovsky (1954) proposes that these two categories are;

- (a) Technological externalities – knowledge externalities, and
- (b) Pecuniary externalities.

Technological externalities identify the effects that non-market interactions have on firms, through some processes that have direct effect on the utility of a firm. These processes may also have effects on the production function of a firm and even on individual players in the industry (Fujita and Thisse, 2002). Pecuniary externalities on the other hand refer to the by-products of interactions within markets that are limited by the degree of involvement in exchanges between the members of these clusters. The market price mechanism regulates these systems. Pecuniary externalities are therefore most relevant when the markets involved are imperfectly competitive; that is to say that prices, and also the well-being of others in the market are affected by the decisions of one agent (Fujita and Thisse, 2002).

More specifically, Thünen (2012) describes the following as some of the consequences of agglomeration externalities;

1. Due to agglomeration, prices of raw materials are reduced on account of a reduction especially in cost of transport.
2. Low transportation costs translate into lower costs of production which lead to a decrease in prices of a firm's products, making it more competitive on the market.
3. There is a reduction in haulage costs of finished goods due to relative closeness of the firm to its consumer base.
4. Construction costs (incurred in building the firm, and so on) are reduced as the distance between raw materials and the site of construction is significantly shorter.

2.3.1 FA and FD as a measure of Agglomeration

Empirical studies have been conducted over the years to find the effect of agglomeration externalities on a diverse set of parameters including efficiency and productivity. These include studies by Caballero and Lyons (1992), Eberts and McMillen (1999), Paul and Siegel (1999) among others. These studies tried to create linkages between industry size (industry concentration or agglomeration) and the externalities that exist among the farms that belong to these agglomerates. Battese and Tveteras (2006) are pioneers of such empirical studies especially as is relevant to the agricultural sector as they examine the effects of agglomeration externalities on efficiency and productivity in salmon farming in Norway.

This study follows Battese and Tveteras (2006) who captured agglomeration externalities as internal and external factors that have a tendency to influence productivity. The external factors that they modeled into the stochastic frontier and efficiency models are farm density and the size of the regional industry. This study includes both FA and FD in both the stochastic frontier and efficiency models to ascertain their effects on both the output and efficiency. FA (farmer association) captures the size of the soybean industry as pertains to farmer groupings and

concentrations while the FD (Farm Density) represents the number of farms located in a defined area (Battese and Tsveteras, 2006).

Larue and Latruffe (2008) used the same concept to establish the effects of agglomeration externalities on the technical efficiency of French pig farms. They captured the agglomeration externalities by two indexes, first of all as the concentration of farms measured by farms' spatial proximity to each other (Larue and Latruffe, 2008). They also captured agglomeration as vertical and horizontal integrations arising from farmers' interactions with each other leading to better market access, demand-matching and input-sharing, as captured by FA in this study. They then investigated the positive and negative effects of these indexes on the technical efficiency of the pig farms.

In recent times, Hailu and Deaton (2016) estimate the effects of a dairy farm's proximity to other dairy farms, captured as farm density, on its production efficiency. They do this using a stochastic input distant function and the results show that farm density has positive economic effect on the efficiency of dairy production in Ontario.

2.3.2 Agglomeration Externalities in Agriculture; Implications on Technical Efficiency and Productivity

In agriculture, agglomeration externalities may either be positive or negative based on spatial concentration. Positive spatial externalities are likely to occur from access to input units (factors) and services such as feed, farming tools, veterinary services, and so on. Positive externalities are also likely to occur as a result of dissemination of information and knowledge through interactions between the farmers. Agglomeration externalities have been closely linked to productivity gains (Larue and Latruffe, 2008).

Studies carried out by Battese and Tveteras (2006), Larue and Latruffe (2008) and Roe *et al.* (2002) have led to the formulation of some theoretical expectations arising from agglomeration externalities in the agriculture sector. First of all, the concentration of farms tends to create positive impacts on their technical efficiency (Larue and Latruffe, 2008). The relationships that are created among farmers due to their spatial proximity further create knowledge spillovers. These relationships also allow these farmers to match labour, as is the case in the soybean sector in the northern part of Ghana (MEDA, 2017).

Another expectation of agglomeration externalities in agriculture is the positive influence that the closeness of farms has on technical efficiency and productivity. In Ghana's soybean sector, there are vertical and horizontal integrations (MoFA, 2011; MEDA, 2017) which account for large concentrations within the sector, leading to better market access and input sharing which in turn lead to positive bearings on technical efficiency and productivity.

There also may arise situations of negative influences on efficiency due to negative externalities that arise from agglomeration (Larue and Latruffe, 2008) and these take a toll on the productivity of the firms involved. These externalities could be due to an unfavourable increase in competition over raw materials or clientele, spread of diseases among crops, lack of water for irrigation, pollution, and so on.

Identification of externalities of agglomeration and the effect that they have in agriculture have undergone a revolution since very early empirical studies (Glaeser *et al.*, 1992; Henderson *et al.*, 1995). There is emphasis on three main indicators of agglomeration, according to Agovino and Rapposelli (2014), and these are as follows:

1. Marshall, Arrow, Romer (MAR) Externalities

2. Jacobs Externalities
3. Porter Externalities

MAR Externalities

These are usually created via spillovers of knowledge and information between firms that belong to the same sector. Knowledge spillovers between firms are therefore stimulated by spatial agglomeration and regional specialization and this leads to expansion and augmentation of the local industry (Cainelli and Leoncini, 1998) and this could have an influence on the way that inputs are combined to produce outputs (Agovino and Rapposelli, 2014). The MAR theory suggests a monopolistic market where players in the industry are allowed to protect their novelties and dispense them more efficiently. The MAR externalities are defined by an indicator specified as:

$$MAR = \max_i(s_{ij}s_j) \quad (2.1)$$

where s_{ij} is the ratio of employed people within the j th sector in the i th region to the total employed in the i th region, s_j is the ratio of employed people in the j th sector at country level to the total employed at country level (Duranton and Puga, 2000).

Jacobs Externalities

Jacobs externalities are centered on the assumption that variety in industry can promote and enhance long-term development via the exchange of knowledge between diverse production units (Jacobs, 1969). The perfect competition market form is the most appropriate for this type of externality because it levels out the playing field and makes opportunities for growth equally available to all in the industry (Cainelli and Leoncini, 1998).

Porter Externalities

Porter externalities are a combination of MAR and Jacobs agglomeration theories. Like MAR, Porter argues that knowledge spillovers within specialized clusters can help improve decision-making which can in turn increase efficiency and stimulate growth. Local competition and input sharing can foster the pursuit and adoption of technological innovation, such as the use of improved seeds. Porters externalities are maximized when there are specialized competitive firms that are in clusters.

2.4 Returns to Scale, Economies and Diseconomies of scale

The production frontier can be characterized in relation to returns to scale (RTS). The RTS expresses the relationship that exists between the proportionality of change in inputs used in a production system to the resultant proportionality of change in output (Fried *et al.*, 2008). It expresses the impact of output expansion on average costs of production and is characterized by the effect of increased output on average cost when there is an equivalent increase of all inputs in the long run (Doll and Orazem, 1984).

There are 3 main categorizations of returns to scale and these are increasing returns to scale, decreasing returns to scale and constant returns to scale. Increasing returns to scale is said to occur when increases in output is proportionally greater than increase in inputs during production. This leads to efficiency of production as it exhibits the combination of fewer quantities of input to produce an output (Salim, 2006). The opposite is the situation of decreasing returns to scale, which shows a production system exhibiting increases in output in less than proportionate quantities to increases in input. Here the output produced is less than the increased input even though there still is increase in the output (Fried *et al.*, 2008). Constant returns to scale is said to happen when the rate of increase in input used in production is equal to the increasing rate in the output. Fried *et al.*

(2008) also describe the variable returns to scale (VRS) frontier as one that exhibits aspects of all the three types of returns to scale in different regions.

Economies of scale are closely linked with returns to scale (Doll and Orazem, 1984) as it describes output levels with respect to input quantities used and also incorporates a cost component (Fried *et al.*, 2008). Reduction in average costs of production with increases in output size or quantity leads to economies of scale. Diseconomies of scale occur as the scale of production continues to increase leading to increase in average cost of production with increase in output. This leads to inefficiency especially in large organizations. Economies and diseconomies of scale are therefore the advantages and disadvantages of large-scale production in the long-run. It is critical to examine these phenomena as they invariably tell on the efficiency of production.

Economics and diseconomies of scale could either be internal or external. Internal economies of scale are merits enjoyed by the firm as it expands or increases quantum of output, and these advantages are due to certain adjustments made within the firm. External economies are therefore the benefits enjoyed by the firm as the industry it operates in grows larger. The same applies for diseconomies of scale, only that in this case it refers to the cost disadvantages that the firm experiences as a result of expansion within the firm (internal diseconomies of scale) or expansion in the industry that the firm belongs to (external diseconomies of scale) beyond the optimal size (Doll and Orazem, 1984; Fried *et al.*, 2008).

2.5 Productivity Measurement

The classical definition of productivity is that it is the ratio between an output of a production system and all the factors that contributed to this output (Fried *et al.*, 2008). Productivity of any production unit is the ratio of (or relationship between) its output to its input (Lovell, 1993). Productivity is therefore the output realized per input used in production and can either be

estimated as Marginal Physical Productivity (MPP) or Average Physical Productivity (APP), also referred to as Partial Factor Productivity (Fried *et al.*, 2008). Marginal Physical Productivity deals with per unit increments and is defined as the rate of change in output per unit change in the quantity of input. The Average Physical Productivity however describes the ratio of quantity of total output per unit to variable input when all other inputs are held fixed. It is also the ratio of total physical product to quantity of variable input (Fried *et al.*, 2008). To illustrate the functional forms, the APP and MPP can be mathematically represented as;

$$APP_{Input} = \frac{Output (Y)}{Input (x)} = \frac{Y}{L} \quad (2.2)$$

$$MPP_{Input} = \frac{\delta Y}{\delta x} = f_L \quad (2.3)$$

Diminishing marginal productivity will however set in when an upsurge in the use of any additional input leads to lower output levels per unit input (productivity) or translates into a less than proportionate increase in quantity produced. This may occur when an input is indefinitely employed while all other inputs of production are held constant (Kibaara, 2005; Lovell, 1993).

Productivity is easiest calculated when a single output is produced from a single input in a production system. It however becomes necessary to aggregate the inputs and outputs if several inputs in differing quantities are used to produce several outputs. This makes it possible therefore to measure productivity as the ratio of two scalars (Fried *et al.*, 2008)

Productivity can further be categorized into Partial and Total Factor Productivity. Productivity is described as Partial Factor Productivity when only one production factor is concerned, and it takes into consideration the contribution of one input to total output. Total Factor Productivity (TFP) on the other hand refers to all the factors of production and measures the total output of a production

process to all inputs used. This productivity measure does not show the interactive process between the individual inputs and output as it aggregates all inputs and output. Partial Factor Productivity is relatively easier to compute due to the absence of aggregation complications.

$$PFP = \frac{Y}{X_i} \quad (2.4)$$

$$TFP = \frac{\sum_{i=1}^n Y_{it}}{\sum_{i=1}^n X_{it}} \quad (2.5)$$

Where Y denotes output, X_i denotes the input levels and X_{it} represent the quantity of inputs used over a period of time (t).

The Multiple Factor Productivity (MFP) also measures productivity as a ratio of combined inputs to the total output produced (Fried, 2008; Kibaara, 2005). For this aspect of productivity to be possible, all inputs must be expressed in the same unit of measurement. The MFP can be generally specified as;

$$MFP = \frac{Y}{\sum_{i=1}^n X_i} \quad (2.6)$$

where $\sum_{i=1}^n x_i$ is the sum of all inputs used in the production system.

2.6 Efficiency

Issues often arise as to exactly what efficiency is as some authors do not make a distinction in the definition of efficiency and productivity. Cooper *et al.* (2000) and Sengupta (1995) define both technical efficiency and productivity as a ratio of output to input. Fried *et al.*, 2008 believe that productivity and efficiency are conjoining terms but rather than describe efficiency as the output-input quotient of a firm, it can be described as the differences in the quantities of input and output which describes the best possible production frontier for the firm in its industry.

Efficiency of production can thus be expressed as comparisons between the actual (observed) and peak values of the firm's input and output levels (Lovell, 1993). This can be expressed as the ratio of the actual to the optimal levels of the firm's output and input. Lovell (1993) also describes the efficiency of a firm as the relationship between the minimum or maximum obtainable potential output and the input needed to produce the output expressed as a ratio. The optimum output is therefore expressed in terms of production possibilities and the efficiency is described as being technical (Fried *et al.*, 2008).

Koopmans (1951) describes an input-output vector as being technically efficient only when it is possible to increase some output in the production system by decreasing some other output, or decreasing an output is only possible by increasing some other output in the same production system. Thus technical efficiency describes the combination of inputs variables in a way in which no higher output levels can be realized from such a combination without negatively affecting the output of another product (Koopmans, 1951). Farrell (1957) describes Koopmans' observations about technical efficiency as being relevant when considered in relation to the best observed production practice in the sector, by virtue of which there can be differentiation between efficient and inefficient production systems.

Fried *et al.* (2008) put forward that the efficiency of the firm is very closely related to Pareto optimality. If during (of intermediate goods) or after production (of final goods) there is still the possibility of increasing output levels or decreasing input levels, then the production bundle is not Pareto optimal.

Farrell (1957) also observes that efficiency of production relies on the ability and skill with production managers to identify and choose the most efficient input-output bundle considering existing input and output prices, also taking into consideration the overall objective of the

producer. He also argues that it is possible to empirically estimate a firm's efficiency and suggests a pioneering technique of estimating the efficiency frontier by observing real situations of production. Parametric estimation methods, as used by Berger and Mester (1997) and Farrell (1957), non-Parametric estimation methods as used by Seiford and Thrall (1990) and semi-Parametric estimation methods as used by Simar and Wilson (2007) have evolved from the studies on relative measure of efficiency developed by Farrell.

2.7 Production Function Analysis and Efficiency Measurement

The notion of production involves the transformational process that a given set of inputs goes through to be turned into an output(s). The production process churns out both waste and the actual product, the latter being the most beneficial to the producer. According to Coelli *et al.* (2005), the production function explains the relationship that is present between the input and output, and represents the optimum output level that can be achieved from each input factor. The productivity-efficiency relationship is such that if firms are technically efficient, then they operate on the production frontier. Firms are said operate below this frontier when they technically inefficient (Coelli *et al.*, 2005).

The main input variable classifications in agriculture, land, capital, labour and management, are what are usually combined to produce an output, with the aim of maximizing profit, utility, or output; or minimizing cost (Olayide and Heady, 1982). In production, the variability in the quantity of input used determines invariably the variability in the quantity of output. The continuous and differentiable nature of the production function enables the estimation of rates of returns (Olayide and Heady, 1982) based on output levels.

2.7.1 Types of Efficiency

Technical efficiency is identified as being only one of the three main types of efficiency, the other two being Allocative and Economic efficiency (Farrell, 1957).

Technical Efficiency

Under any given technology, technical efficiency is the capacity of firms to produce the required quantity of output using minimum quantity of inputs (Fried *et al.*, 2008; Shalma, 2014). From a combination of different sets of input, a more technically efficient firm is able to produce larger quantities of output than other firms using the same quantities of input (Fried *et al.*, 2008). In the situation where the output is predetermined, the ability of the firm, while producing the output, to minimize its input in the production system is also said to be technical efficiency.

The measurement of the technical efficiency of a firm relies on the distance between the actual output produced of a firm and the most optimum production frontier (Pascoe and Mardle, 2003; Fried *et al.*, 2008; Farrell, 1957). By comparing and contrasting the actual output and potential output, the technical efficiency levels can be ascertained (Greene, 1993).

Some socio-economic factors may have significant impact on the efficiency of a production unit. These factors include human and monetary capital, socio-economic characteristics and demographics, and institutional factors of the farmers (Bhosale, 2012). These factors may either be endogenous or exogenous, putting a clear differentiation between factors that are within and outside of the farmers control (Battese and Tveteras, 2006).

Technical efficiency studies are very key to ensuring higher productivity in agriculture. Several studies including Onumah *et al.* (2010), Battese and Tveteras (2006), and Mohammed *et al.* (2016)

have adapted technical efficiency studies across several agricultural sectors of fisheries and crop production.

There are three main classifications of technical efficiency employed especially in farm efficiency studies; these are deterministic parametric estimation, non-parametric mathematical programming, and the stochastic parametric estimation. The non-parametric method of measuring efficiency is further divided into two. Chavas and Aliber (1983), and Chavas and Cox (1988) employ the first type by measuring efficiency basing their measurements on the neoclassical theories of consistency, recoverability and extrapolation, and restriction of the production form (Shalma, 2014).

The second measure (non-parametric estimation), as developed by Farrell (1957), broke efficiency down into two constituents of technical and allocative efficiency, which was further expanded by Fare *et al.* (1985), in which disposability of inputs was linked to the restrictive supposition of constant returns to scale. Farrell (1957) postulates that there are multiplicative interactions between the technical and allocative components and this provides a means by which economic efficiency can be measured.

In order to estimate economic efficiency therefore, technical efficiency measurements are a necessary but not sufficient condition (Farrell, 1957). Therefore, it is necessary that both the allocative efficiency and technical efficiency of a firm are estimated to ascertain the economic efficiency of firms and industries.

Allocative Efficiency

The work of Farrell (1957) also introduced allocative efficiency as one of the kinds of efficiency. As technical efficiency investigates the maximum output that is attainable from the combination

of available inputs, allocative efficiency conversely investigates the capacity of the production firm to utilize available inputs in optimal proportions (Etwire *et al.*, 2013). Allocative or price efficiency deals with how well a firm mixes its factors of production and allocates resources to input factors considering prevailing market prices. For inputs used in production, allocative efficiency assumes fixed market prices. It also assumes that output is fixed. Thus, the ability of the producer to coalesce input factors in optimal quantities and proportions (which is constrained by the prices of factors of production) constitutes allocative efficiency. Therefore, allocative efficiency measures the success with which a firm chooses optimal sets of inputs for production, given the prices of the inputs (Fried *et al.*, 2008). Unlike technical efficiency, allocative efficiency does not necessarily measure a firm's success against the production frontier but rather its capacity to generate the most optimum output level from a given set of inputs (Fried *et al.*, 2008).

According to Adinya and Ikpi (2008) and Badunenko *et al.* (2008), it is critical that extensive studies in allocative efficiency be undertaken in Africa since the majority of farmers are allocative inefficient due to their inability to make the most of the resources at their disposal. Such studies are however difficult to carry out due to the difficulty in obtaining the prices of input factors, which are very key requirements in estimating allocative efficiency. Apart from information on prices of factor inputs, it is also necessary to be willing to assume that the major objective of the firm is cost minimization (Uri, 2001).

Efficiency studies are incomplete without allocative efficiency studies especially for developing countries with relatively higher scarce resources. In recent times there have been studies that have tried to estimate allocative efficiency by obtaining and using upper and lower bounds of economic efficiency especially when information about input prices are incomplete or not readily accessible

(Kuosmanen and Post, 2001). It is therefore an important allocative efficiency measure especially for countries that do not have readily available and/or reliable input price information.

Economic Efficiency

Farrell (1957) defines economic efficiency as the capability and capacity of a firm to churn out a predefined output while incurring the least cost. Economic efficiency describes the state in which every resource at the disposal of the firm is optimally allocated in the production process while waste and cost are minimized. It describes a situation where it is impossible to generate more output (welfare) from the resources available (Lovell, 1993). Economic efficiency therefore includes both technical and allocative efficiency. It is however worth noting that in a real life setting, there is a difficulty in determining the optimal output obtainable by a production system (Kumbhakar and Lovell, 2003).

The principles of economic efficiency are based and bound by the theory of scarce resources indicating that it is not possible for any economy to function at its highest capacities at all times. This is because of the scarcity of resources to do that. One important advantage of economic efficiency studies is the comprehensive evaluation of production units taking into consideration input and output factors (Coelli, 1995).

2.7.2 Other Considerations for Efficiency

Scale Efficiency

A firm is considered as scale efficient when the extent and size of its operations are optimal so that when the size is modified in any way, the production unit is rendered less efficient. It indicates whether or not a firm is operating and functioning at its optimal size and capacity. This type of efficiency has been developed over the years in three distinct ways (Fried *et al.*, 2008). Farrell (1957) used the most restrictive technology that had a strong disposability of inputs and exhibited

constant returns to scale. Charnes *et al.* (1978) expressed Farrell's model as a framework of linear programming while Banker *et al.* (1984) showed that measuring efficiency by virtue of constant returns to scale can further be expressed as the product of a scale efficiency measure and a technical efficiency model. The third model of scale specifies the production function as a non-linear function (example a translog or Cobb-Douglas function) from which one can directly compute the scale measure (Sengupta, 1994).

Structural Efficiency

This was developed by Farrell (1957) to determine the extent to which an industry keeps up with the production performance of its own best practice firms (Fried *et al.*, 2008). It therefore measures the level of the degree of an industry at which its farms are of maximum potential size and also the degree to which production level of that industry is optimally allocated, in the short-run. An industry is therefore comparatively efficient structurally if the distribution of its best firms is more concentrated closer to its efficiency frontier for the entire industry. Bjurek *et al.* (1990) proposed a computation for structural efficiency measurements by developing an average unit for the entire agglomeration of firms and then computing the individual measures of efficiency for this unit (Fried *et al.*, 2008).

2.8 Measurement of Efficiency

Efficiency (including farm efficiency) studies have incorporated several approaches of efficiency studies under the parametric (statistical) and non-parametric concepts, one of these approaches being to estimate the efficiency frontier, where producing at any point below this frontier is regarded as production that is inefficient.

Efficiency studies have further categorized parametric measures of efficiency into neutral and non-neutral frontiers. Aigner *et al.* (1977) and Meeusen and van den Broeck (1977) used the neutral

frontier parametric method in their measure of maximum output and production efficiencies. They did this by specifying a composed error term to the conventional production function. The non-neutral approach employs the use of a production function form of varying coefficients.

2.8.1 Non-Parametric Approach

This approach estimates production efficiency without imposing any structure on the distribution of the population. The general assumption of this approach is that the failure to reach optimum output is not due to errors but rather to inefficiency. This method does not require the specifying of a functional relationship between outputs and inputs (Fried *et al.*, 2008). Unlike in the parametric approach, this approach does not require defining the frontier line and stochastic error term. Also, no assumptions are made about the functional form of the density of efficiency values.

The non-parametric approach is oriented by an input framework which is based on the input efficient boundary and the input requirement set (Aigner and Chu, 1968; Fried *et al.*, 2008). This approach aims at minimizing input levels while maintaining present output levels. The main non-parametric estimators are the Data Envelopment Analysis (DEA) and the Free Disposal Hull (FDH).

Charnes *et al.* (1978) developed the DEA as an extension of Farrell's relative efficiency concept and assumes the production set's free disposability and convexity. This approach constructs a non-parametric frontier for sample data using linear programming while efficiency measures are computed in relation to the frontier (Coelli *et al.*, 2005). In using the DEA estimator, unnecessary restrictions about the functional form that may distort efficiency measures and affect the analysis can be avoided. This is because the analysis can proceed without necessarily having knowledge of the algebraic form of the input-output relationship (Coelli *et al.*, 2005; Fraser and Cordina, 1999).

Deprins *et al.* (1984) proposed the FDH estimator and it is meant to represent a more general form of the DEA estimator in that it is dependent on the assumption of free disposability (Fried *et al.*, 2008). Thus, the FDH does not restrict itself to convex technologies and this gives it an advantage due to the scarcity of empirical and theoretical justification for using convex production axioms in efficiency studies.

2.8.2 Parametric Approach

This analytical approach to efficiency measurement is described by a known mathematical production frontier function which depends on some unknown parameters. Efficiency frontier models are classified according to how the functional form has been specified for the frontier function, the type of data that is to be analyzed and the presence of *noise* in the data (Fried *et al.*, 2008). The advantages of this approach include the fact that the estimators used have statistical properties and also there is economic interpretation of the parameters. The parametric frontier estimation is categorized into deterministic and stochastic techniques depending on how the error term is specified (Aigner *et al.*, 1977; Aigner and Chu, 1968). The stochastic technique is estimated by an econometric technique while the deterministic technique can be estimated with either mathematical programming (Aigner and Chu, 1968) or an econometric approach.

2.9 The Deterministic Frontier Model

The non-parametric method of the deterministic approach to efficiency measurement is mostly used in efficiency studies (Fried *et al.*, 2008). Following this approach means that models employed in the estimation do not account for statistical noise. The deterministic frontier production function as developed by Aigner and Chu (1968) is expressed as:

$$Y_i = f(X_i; \beta) \cdot \exp(-u_i), u_i \geq 0 \quad (2.7)$$

where u_i represents the technical inefficiency effect of the i th firm. $Y_i \leq f(X_i; \beta)$ when $u_i \geq 0$. Therefore, the technical efficiency of the deterministic frontier model is expressed as:

$$Y_i = \frac{f(X_i; \beta) \cdot \exp(-u_i)}{f(X_i; \beta)} = \exp(-u_i) \quad (2.8)$$

The foremost merit of the deterministic frontier model is that it is easy to use. However, Fried *et al.* (2008) identify the impact of super-efficient outliers as one of the main demerits of the model, stating that this could tell on the overall outcome of the analysis. Russell and Young (1983) also criticized the deterministic frontier model for its underlying assumption that the firm decision-maker or manager controls all deviations from the efficient frontier and that these deviations are endogenous.

2.10 The Stochastic Frontier Model

The stochastic frontier model was developed by Meeusen and van den Broeck (1977) and Aigner *et al.* (1977) and it incorporates both endogenous and exogenous factors in the estimation of the efficiency of a firm. Thus, the stochastic frontier model decomposes the error term of the specified production function into two parts. One part of the error term caters for random shocks while the other accounts for the inefficiency effects (Aigner *et al.*, 1977). The advantage of the stochastic frontier model over the deterministic frontier model is that it identifies and makes a clear distinction between deviations occurring as a result of stochastic noise resulting associated with production and deviations occurring as a result of inefficiency.

2.10.1 Model Specification of the Stochastic Frontier Function

The stochastic frontier model specifies a stochastic frontier for cross-sectional data as:

$$Y_i = f(x_i; \beta) \exp(\varepsilon_i) = f(x_i; \beta) \exp(v_i - u_i), i = 1, 2, \dots, N \quad (2.9)$$

where Y_i represents the output level, x_i represents the vector of inputs and other explanatory variables that are associated with the firm/farm, β is the vector of unknown parameters to be estimated and ε is the error term ($V_i - U_i$). V_i is the noise error term that is outside the firm's control (capturing other random effects) and U_i captures the non-negative inefficiency error term.

To ensure that all of the observations of efficiency lie on the stochastic production frontier or below it, U_i is non-negative ($U_i \geq 0$) (Aigner *et al.*, 1977; Coelli *et al.*, 2005; Onumah *et al.*, 2010). The technical inefficiency effect, with reference to Battese and Coelli (1995), is specified as:

$$U_i = Z_i \delta + W_i \quad (2.10a)$$

where U_i represents the endogenous error term, Z_i the vector of explanatory variables that is associated with technical inefficiency effects, δ the vector of unknown parameters, and W_i the random variables, such that $W_i \geq Z_i \delta$. The technical efficiency can further be expressed as the ratio of observed output to the potential maximum output, assuming that any deviations are stochastic (Boshrabadia *et al.*, 2008). This study however specifies the inefficiency model as;

$$\mu_i = Z_i \delta \quad (2.10b)$$

2.11 Functional Forms for Production Frontier Estimations

Mathematical models employed by empirical studies for estimation purposes may be specified diversely depending on the objective of the researcher. The specification of an economic model is therefore guided by the objectives and goals of the study and the conditions underlying the research. Some commonly used functional forms for production frontier analysis include the Cobb-Douglas, Translog, Leontief, Logarithmic and Spillman production functions (Griffin *et al.*, 1987). This review considers two of the most common functional forms.

The Cobb-Douglas Production Function

The Cobb-Douglas production function is a double-logarithm production model that expresses input and output variables as logarithms. The Cobb-Douglas model can be expressed generally as;

$$Y = aX^b \quad (2.12)$$

where Y represents the output, X the input variables with a and b being unknown parameters to be estimated. In its general form the Cobb-Douglas function is a non-linear multiplicative function that can be linearized by taking the logarithms of the variables used in the model. After applying the logarithmic transformations to linearize it, the generalized Cobb-Douglas function in equation 2.12 is expanded into;

$$\ln Q = \beta_0 + \sum_{i=1}^n \beta_i \ln X_i \quad (2.13)$$

The Cobb-Douglas production function assumes constant returns to scale with elasticity of substitution equal to one. It is however limited by the assumption of constant returns to scale and this can be problematic (Hassani, 2012). Also, the function assumes a market form of perfect competition. Some efficiency studies have however employed the Cobb-Douglas production function successfully. Hassani (2012) employed the Cobb-Douglas function in time-cost analysis in the construction sector while Onumah and Acquah (2010) employed it in the estimation of productivity differentials between family and hired labour aquaculture in Ghana.

The Transcendental Logarithmic (Translog) Production Function

This production function is a generalized form of the Cobb-Douglas production function in which the number of parameters expands with increases in the number of production factors (Pavelescu, 2011). The transcendental logarithmic production function provides a second order approximation to an arbitrary twice differentiable function. This enables the testing of structural hypotheses like

separability with fewer maintained restrictions than necessary. The merits of the translog function include the absence of any restrictions on the elasticities of substitution of the inputs used in production. The general translog functional form is specified as:

$$\ln Y = \beta_0 + \sum_{j=1}^n \beta_j \ln X_j + \frac{1}{2} \sum_{j=1}^n \sum_{k=1}^n \beta_{jk} \ln X_j \ln X_k \quad (2.14)$$

The translog production function cannot give a second order approximation to an arbitrary weakly separable function given any input, and so is referred to as separable-inflexible (Coelli *et al.*, 2005). The translog function produces fewer parameters after imposing separability and this does not allow it to maintain flexibility. The contribution of flexible forms depends on their ability to place fewer restrictions prior to estimation and not in their approximation properties (Coelli *et al.*, 2005).

2.11.1 Criteria for Choosing Functional Forms

The purpose of analysis determines the choice of functional form, however, it is impossible to determine for any given relationship, the true functional form (Griffin *et al.*, 1987). In choosing a functional form therefore, one needs to be sure of which one is the best suited for the job at hand. One of the most important criteria for selecting a functional form is by considering how a production technology aligns with specific theoretical properties. In choosing a functional form, some hypothesis governing the analysis are chosen for testing while the other hypotheses are assumed to be true and remain testable. Therefore, in making a choice of a functional form, the model is considered useful if the hypotheses governing it is acceptable and useful. An unrestrictive functional form may however be used especially when a strong empirical or theoretical basis for the adoption of a hypothesis is absent.

Another criterion for the selection of a functional form is the availability of data and resources for computing the estimates. For instance, for functional forms that do not follow linear least square

procedures for estimations, absence of adequate data for analysis may be problematic. In choosing a functional form, one may also consider issues of conformity to the data (goodness-of-fit) where a model is chosen based on data-specific considerations (Griffin *et al.*, 1987). One method of finding the model that best fits the data is by testing nested and non-nested models (Judge *et al.*, 1985).

Application-specific features of the functional form can be a quality looked into for consideration as an appropriate model. For instance, for optimization and simulation purposes, researchers might look for certain desirable features in considering the choice of a functional form. Some properties to look out for in choosing a functional form include the linearity, robustness, parsimony, and regularity of that model.

2.12 Determinants of Inefficiencies

Kumbhakar and Lovell (2000) outline three major approaches to incorporating exogenous variables to measure technical efficiency variations. These are the initial approach, the two stage approach and the single stage approach.

The Initial Approach

The assumption governing this approach to measuring the determinants of inefficiencies is that the exogenous factors have an effect on production. The stochastic frontier model for the initial approach is specified as:

$$\ln Y_i = \ln f(x_i, z_i; \beta) + v_i - u_i \quad (2.15)$$

where Y_i , x_i , z_i and β represent the output, input variables, exogenous variables and the production parameters respectively. The vector of the exogenous variables (z_i) is assumed to influence the structure of the production function by directly influencing output. Due to the assumption that

exogenous variables are uncorrelated with the error terms (v_i and u_i), variations in efficiency are not explained adequately by this model.

The Two Stage Approach

The two stage approach tries to link variations in the estimated efficiency to production-specific variations in the exogenous variables. The first stage of the two stage approach estimates the production frontier parameters under independence and distributional assumptions and then regresses the estimated inefficiency effects on the exogenous variables in the second stage. This is represented as:

$$E(u_i | v_i - u_i) = g(z_i; \gamma) + \varepsilon_i \quad (2.16)$$

The two stage approach imposes the assumption that the exogenous variables have an indirect effect on the output variable by virtue of their effect on efficiency. Unlike in the initial approach, the structure of the production technology is not influenced by the exogenous variables. The exogenous variables are deemed to affect the efficiency of production. The Ordinary Least Squares estimation method is not appropriate in this approach since the dependent variable is bound by zero and one. The two stage approach is limited by the violations of the identical distribution of the u_i when the technical inefficiency effects are regressed on some specific farm characteristics.

The Single Stage Approach

In this approach, the effects of inefficiency are defined as an explicit function of some known factors to production (Kumbhakar and Lovell, 2000). The Maximum Likelihood Estimate procedure estimates all the parameters of the productivity and inefficiency models and explains variations in the inefficiency. This approach circumvents the problem of identical distribution.

Using the single stage approach, Battese and Coelli (1995) specify an inefficiency model as:

$$\mu_i = \delta_0 + \delta_i Z_i \quad (2.17)$$

where Z_i represents some socioeconomic factors that influence technical inefficiency and the δ s are parameters to be estimated.

2.13 Exogenous Factors

Exogenous factors have implications on farm efficiency and productivity. In agriculture studies, we identify farm specific factors, farmer specific factors and institutional factors as some of the main exogenous factors. Farm and farmer specific factors include some identified socioeconomic and exogenous factors that influence the efficiency of farmers positively or negatively. These factors could either be statistically significant or otherwise depending on the data collected during the study. They include the gender, age, educational level and experience of the farmer, farm size, seed fertilizer and labour. Onumah *et al.* (2013) identify some other farm specific factors as access to credit, household size, extension contact and the distance between the farm and residence of the farmer.

Due to extensive efficiency studies conducted in agriculture, the relationship between some farm specific factors and efficiency are almost always predictable in their *a priori* expectations. For instance, level of education, access to credit and membership to farmer associations (FA) usually have a positive influence on efficiency and productivity.

Institutional factors are also significant determinants of farming. These are factors related to social institutions, tenancy issues and land ownership and they have bearings on the size of the field, the farming system/type and invariably the productivity.

2.14 Econometric Packages for Efficiency Analysis

In estimating different kinds of efficiency, researchers have employed the use of a diverse list of econometric tools some of which include Ox-SFAMB (as used by Onumah *et al.* (2010)), STATA, LIMDEP, GAUSS and SAS. The FRONTIER 4.1 (Coelli, 1996) and LIMDEP (Greene, 1995) are

very commonly used econometric packages for efficiency analysis. The Ox-SFAMB software (Brümmer, 2003) specified under the FRONTIER 4.1 is also being widely considered for efficiency estimations. This study as well as other empirical studies, including the efficiency studies on the fisheries sector of Ghana (Onumah *et al.*, 2010), have employed the Ox software in technical efficiency analysis. The FRONTIER 4.1 is designed specifically for stochastic frontier estimations. The LIMDEP is however more general in its usage for diverse non-standard econometric computations (Sena, 1999). For the FRONTIER 4.1 econometric tool, the estimates of efficiency are produced as a direct output from the package and this is advantageous as one can specify the assumptions of distribution for the inefficiency term estimates in a program control file (Coelli, 1996).

2.15 Empirical Studies Utilizing the Stochastic Frontier Approach

Aigner *et al.* and Meeusen and van den Broeck in 1977 individually introduced the stochastic frontier production function (Battese and Coelli, 1995) and this has provoked a lot of research to apply the model and also to expand it. Stochastic frontier analysis provides an alternative to the use of econometric techniques to estimate frontier functions (Coelli *et al.*, 2005). It helps, especially, to eliminate noise or disturbance in data, which is captured by a symmetric component (comprised of influences outside the control of the firm, instigated by statistical noise, measurement errors and other non-symmetric parameters) and a one-sided (asymmetric/non-positive) component which relates efficiency to the stochastic frontier and captures influences within the control of the firm.

Several studies on productivity and efficiency have been carried out in the agricultural sector that try to measure and estimate productivity and efficiency within the sector for a diverse number of crops and animals. Especially for developing, and underdeveloped, countries, where resources are

relatively meagre and scarce, stochastic frontier studies provide investigations into developing and adopting better technologies that increase efficiency (Shalma, 2014).

The stochastic frontier function puts forward that there are existing technical inefficiencies of production that are involved in every production process (Battese and Coelli, 1995) and which inevitably tell on the efficiency with which an output is produced. These measures of efficiency are important as they are an important factor and indicator for increasing productivity.

Battese and Corra (1977) first applied the stochastic frontier model on farm-level data by estimating Cobb-Douglas production frontiers (both the stochastic and deterministic frontiers) for Australia's grazing industry. They found that the variance of the farm effects formed a very significant share of the total variability of the logarithm of the value of sheep production (Shalma, 2014). This study encouraged other applications of the stochastic production frontier model in agriculture.

Onumah *et al.* (2010) also employed the stochastic frontier function to assess the technical efficiency and the subsequent determinants of fish farms in Ghana using cross-sectional data. The analysis enabled their research to estimate elasticities of output for some inputs, enabling estimation of efficiency in the fish farming industry in Ghana. Battese and Coelli (1995) adopted the stochastic frontier approach on panel data collected on paddy rice farms in India, and were able to ascertain the technical efficiency levels, especially of older farmers against younger ones. Awudu and Huffman (2000) conducted a study on rice farmers' efficiency in the Northern part of Ghana, where they used a normalized stochastic profit function frontier to estimate inefficiency in the rice sector and how it affects profit. The study showed that the discrepancy in the frontier profit and observed profit was as a result of both technical and allocative efficiency.

Other studies conducted that have incorporated the stochastic frontier production function to estimate and assess efficiency include technical efficiency studies on soybean carried out by Etwire *et al.* (2013) and Mohammed *et al.* (2016). Perhaps one of the most ground-breaking studies conducted to assess technical and productive efficiency using the stochastic frontier approach is by Battese and Tveteras (2006) to assess the implications of agglomeration externalities for the production frontier and efficiency of Norwegian salmon farming.

A technical efficiency study was conducted by Liu and Zhuang (2000) on post-collective Chinese agriculture (Shalma, 2014) where, with the use of joint estimations of the stochastic frontier model, they were able to deduce that technical inefficiency could be explained by interactions within the inefficiency models.

In conclusion, this section of the study reviewed literature on the agglomeration externalities that arise from clustering. It also examined the conditions necessary for these externalities and the merits and demerits that may arise from these agglomerates, some of which include knowledge spillovers and input sharing for the former and pest infestations for the latter. The chapter also addressed the effects that these agglomerations have on technical efficiency and the production frontier, establishing that for especially small-holder farms, increase in farm density (farm concentrations) up to a certain threshold can have positive implications for efficiency and productivity where economies of scale come to bear. The chapter reviewed literature on productivity and efficiency studies and the various methods of measurement, noting that there is a link between efficiency and productivity when the way that inputs are used in a production system leads to optimum levels of the output. Agglomeration and the externalities that arise from it can have economic implications on the productivity and technical efficiency of a production system of a firm or farm (Battese and Tveteras, 2006).

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter outlines the theoretical and contextual frameworks of the study as well as the methods of analysis that the study adopted to achieve its main and specific objectives, the main objective being to assess agglomeration externalities, productivity and technical efficiency of soybean farms in the Upper East and Upper West Regions of Ghana. The chapter also addresses the methods of data collection, the sampling procedure adopted by the study and a description of the study area.

3.2 Conceptual Framework

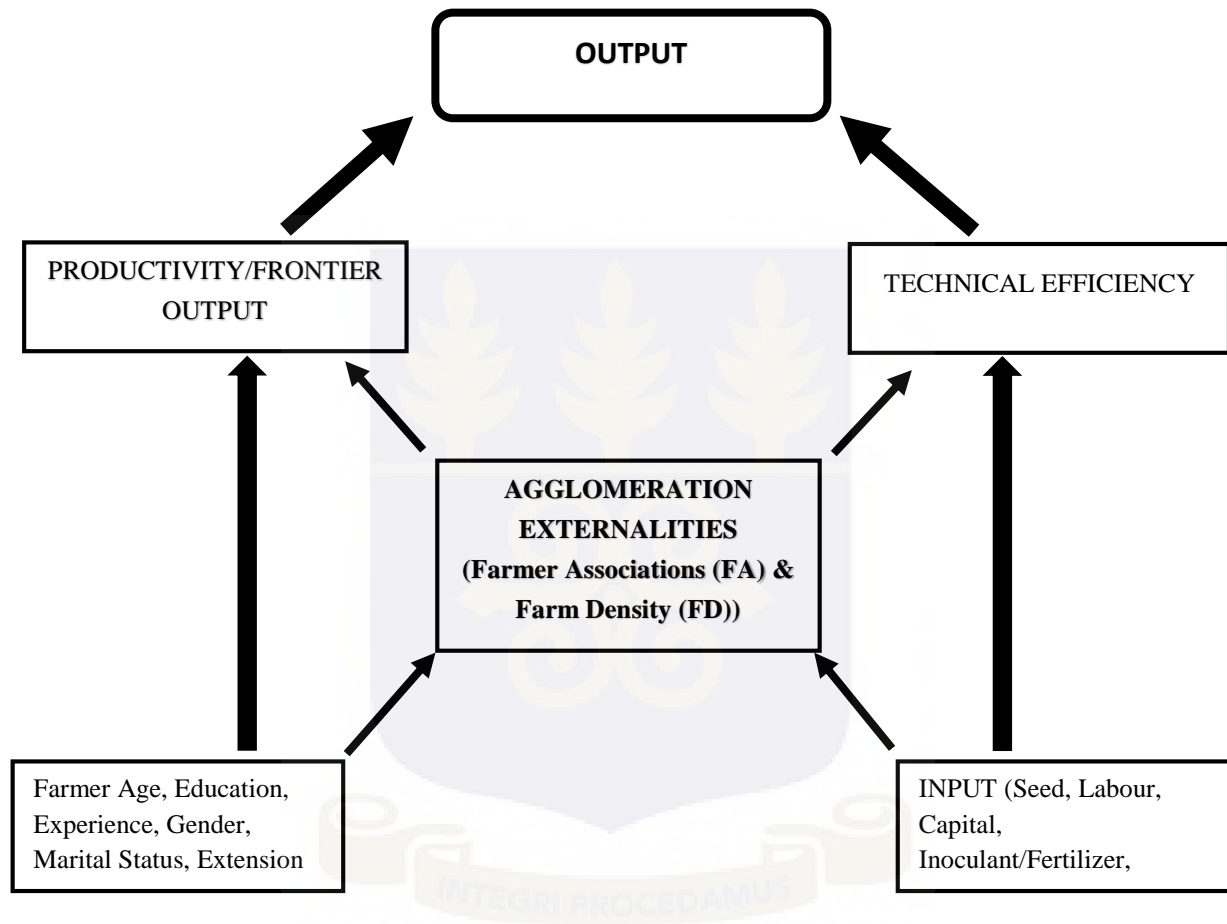
The framework of the concept that governs this study links agglomeration externalities, efficiency and productivity in a way that describes how they interact with each other in an economic system (Figure 3.1).

The externalities that arise as a result of the creation of agglomeration economies, may have some effect on technical efficiency and also on the productivity of the farming sector (Battese and Tveteras, 2006; Maciente, 2013). Therefore, aside the variables that directly affect technical efficiency and productivity, such as input and socio-economic demographics of the farmers (Antwi *et al.*, 2016), agglomeration externalities also have direct effect on efficiency of input combinations, and on the production frontier (Battese and Tveteras, 2006). Factors that affect technical efficiency and productivity (both endogenous and exogenous factors) may also influence the formation of clusters within an industry (Parr, 2002a).

Assessing the effects of the externalities on these two parameters will influence policy and/or decision-making by policy makers and farmers on the most profitable, efficient and productive

ways of running their business, including whether to form or join farmer groups or be independent (Etwire *et al.*, 2013).

Figure 2.1: Conceptual Framework



Source: Adapted from Battese and Tsveteras, 2006.

Figure 3.1 demonstrates a linkage between agglomeration externalities, productivity and efficiency and how these together influence output. Output levels of a production system are influenced by the technical efficiency and productivity of the farm (Lovell, 1993). The externalities that arise from agglomerations such as demand-matching, specialized labour supply, knowledge spillovers and input-sharing invariably affect the efficiency with which production activities are undertaken.

It also influences the productivity of farms (Larue and Latruffe, 2008) which in turn influence output levels.

3.3 Theoretical Framework

The production frontier model is adopted for this study. Following Aigner *et al.* (1977), Meeusen and van den Broeck, (1977) and Battese and Corra, (1977), we define an error term that consists of an exogenous term (v), made up of factors that the farmer cannot control, and an endogenous term (u) that consists of factors that the farmer is able to control. The u is non-negative, random, independently distributed, and accounts for technical efficiency in production. u and v are independent random variables. The stochastic frontier model is expressed as:

$$y = f(x_i, \beta) e^{v-u} \quad (3.1)$$

where y represents the output (Kg/Ha) scaled down by land size, from output per acre to per hectare so as to avoid dealing with huge land size figures. $f(\cdot)$ represents the production frontier function, u is the endogenous term, which is a random variable that is non-negative and is associated with efficiency of production. v represents the exogenous, traditional random error term. If $u > 0$ there is inefficiency and therefore production falls short of the frontier. If $u = 0$, then the production lies on the frontier and so is therefore efficient (Mohammed *et al.*, 2016). The stochastic frontier model is a translog function given as:

$$\ln y_i = \beta_0 + \sum_r \beta_r + \sum_k \beta_k \ln x_{ki} + \sum_j \sum_{k \geq j} \beta_{jk} \ln x_{ji} \ln x_{ki} + (v_i - u_i) \quad (3.2)$$

$\ln y_i$ represents the natural logarithm of the output of farm i (representing productivity), x_{ki} represents the input levels and the translog form, $\ln x_{ki}$, implies that no *a priori* restrictions are imposed with respect to internal returns to scale (Batesse and Tsveteras, 2006). The translog

production function, which is flexible in nature, allows for farm-specific efficiency measurements and analysis of interactions among variables (Antle, 1984).

Equation 3.2 is further expanded into equation 3 to include agglomeration. The new form is:

$$\ln y_i = \beta_0 + \sum_r \beta_r E_r + \sum_o \beta_o \ln E_o + \sum_k \beta_k \ln x_{ki} + \sum_j \sum_{k \geq j} \beta_{jk} \ln x_{ji} \ln x_{ki} + (v_i - u_i) \quad (3.3)$$

where E_r is agglomeration (captured by FA), E_o is agglomeration (captured by FD), U_i is technical efficiency and x are the input variables. The study also follows Battese and Coelli (1995) as well as Onumah *et al.* (2010) and estimates the technical efficiencies using the technical efficiency model specified as:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{f(X_i; \beta) \cdot \exp(v_i - u_i)}{f(X_i; \beta) \cdot \exp(v_i)} = \exp(-u_i) \quad (3.4)$$

where v_i and u_i are the exogenous and endogenous parameters for farm i . Y_i is the output level for the i th observation and Y_i^* is the maximum potential farm output level, considering that the inputs, X , are combined with maximum efficiency in a situation of ‘best farm practice’. The difference between Y_i and Y_i^* is embedded in the u_i . $Y_i = Y_i^*$ when $u_i = 0$ implying technical efficiency as a result of the production lying on the frontier (Onumah *et al.*, 2010).

Thus, the technical efficiency of production for the i th firm is derived using the technical efficiency model as specified. The model can also be specified as:

$$TE_i = \exp(-U_i) = \exp(Z_i \beta - W_i) \quad (3.5)$$

where for farm i , Z is a vector of all explanatory variables that are associated with the technical inefficiency effects and β is a vector of unknown parameters to be estimated. Thus, the parameters of both the inefficiency model and the frontier production function are concurrently estimated (Batesse and Coelli, 1995). Equation 3.5 can further be expanded to include FA and FD to estimate

the effects of agglomeration on efficiency. One of the Z_i s can represent FD and FA to determine the effect of agglomeration externalities on technical efficiency. The means, μ_i , associated with the technical efficiency effects are assumed to be a function of regional and farm characters and the functional form is specified as:

$$\mu_i = \delta_0 + \sum_{m=1}^M \delta_m Z_{mi} \quad (3.6)$$

3.4 Methods of Analysis

3.4.1 Empirical Model Specifications

Following Battese and Tveteras, (2006) and Battese and Coelli, (1995), the models for the analysis are specified with both a technical efficiency model and a stochastic frontier production model. Both the frontier production and efficiency models incorporate a parameter, E , which represents agglomeration externalities. For this study, the agglomeration externalities (E) is captured by two variables; FA, which represents the number of farmers who belong to farmer associations, and FD which represents the farm density and is defined by the number of soybean farms per square kilometre.

The technical efficiency model is specified in equation 3.6 and caters for the exogenous and endogenous factors v_i and u_i .

3.4.2 Identifying Agglomeration Externalities in The Soybean Sector

Following Battese and Tveteras, (2006), the study set out to identify the agglomeration externalities that exist in the soybean sector. This was done by eliciting information on the two parameters the study adopted for measuring agglomeration, that is E_{FAi} , which represents agglomeration externalities/effects arising from farmer associations, E_{FDi} , representing externalities of agglomeration arising from farm density in the areas of study. FA and FD are thus proxies representing agglomeration externalities in the efficiency and production frontier models.

FA and FD were used as unconventional variables in the models to determine the effect that they have on both technical efficiency and productivity.

Farmers sampled for questioning were asked to indicate whether or not they belonged to any form of farmer association or FBO. For farmers who belong to farmer associations, farm densities were assessed by ascertaining the number of soybean farms located per every square kilometer. Farm Density was not considered relevant for farmers who operate independently, and so data was not collected on it, but proximity to other soybean farms was assessed to establish the level of interaction and externalities, if any, that occurred and arose from such proximity to each other.

3.4.3 The Frontier Model

The production function put forward by Caballero and Lyons, (1990), which takes a log-linear Cobb-Douglas form, was used to assess the elasticities of the output in relation to inputs. The production function is specified as;

$$\ln Y_i = \beta_0 + \sum_{FA} \beta_{FA} E_{FA} + \sum_{FD} \beta_{FD} \ln E_{FD} + \sum_{n=1}^{n=4} \beta_k \ln x_{ki} + \sum_j \sum_{k \geq j} \beta_{jk} \ln x_{ji} \ln x_{ki} + (v_i - u_i) \quad (3.7)$$

where Y_i is productivity (measured in kilograms per hectare), E_{FA} is agglomeration with respect to Farmer Association, E_{FD} is agglomeration with respect to Farm Density and U_i is technical efficiency. The study looks at the implications on productivity from the combination of four inputs (x), namely SEED (Seed) measured in kilograms, K (capital) measured in Ghana cedis (GHS), LAB (Labour) measured in person-days and FERT (fertilizer) which is captured as an intermediate input.

3.4.4 Variables to Assess Productivity

Table 3.1 presents the variables measured to assess productivity, a description of these variables and parameters, their units of measurement and individual *a priori* expectations for them. For the input variables seed, capital, labour and fertilizer, it is expected that the relationship between them

and productivity is positive, indicating an increase in Y (output) with increases in the quantity of input used.

The SEED variable represents the quantity in kilograms of soybean seeds planted by soybean farmers per season. K represents the capital that the farmer invested in his farming activities and is measured in Ghana cedis. LAB is measured by the average number of person-days spent on the farm every season. FERT is captured as an intermediate input and so is measured in Ghana cedis. It represents the monetary value of inoculant used per season for soybean farming.

Seed (Kg), capital (GHS), Labour (person-days) and fertilizer (Kg) are measured as continuous variables. FA is measured as a dummy variable. The study expects that agglomeration externalities for the production model could either have positive or negative effects on productivity.

Table 3.4: Productivity variables, description, unit of measurement and a priori expectations

Variable	Description	Unit of measurement	<i>A priori</i> expectation
Y	OUTPUT	Kg	
Input Variables:			
SEED	Seed	Kg	+
K	Capital	GHS	+
LAB	Labour	Person-days	+
FERT	Fertilizer	Intermediate input (GHS)	+
Agglomeration:			
FD	Farm Density	Number of farms/sq. km	+/-
FA	Farmer Associations	Dummy: 1 = Yes 0 = No	+/-

Source: Survey, 2017

3.4.5 Inefficiency Model

Following Battese and Coelli (1995), the technical efficiencies were elicited and estimated. Here, the efficiency levels of the farms are compared to a frontier of 1 (100%) to determine farmers'

levels of efficiency. There is technical inefficiency when production lies below the frontier (that is $u_i > 0$).

From the base model, the assumption governing the means U_i related to the technical efficiency effects is that they are a function of farm and industry characteristics. The technical efficiency effects are thus assumed to be defined by the inefficiency model specified as:

$$\mu_i = \delta_0 + \delta_{MS} MARSTAT_i + \delta_{EXP} EXP_i + \delta_{EXPSoy} EXPSoy_i + \delta_{AGE} AGE_i + \delta_{GEN} GEN_i + \delta_{EXTNum} EXTNum_i + \delta_{HHS} HHS_i + \delta_{EDUC} EDUCYrs_i + \delta_{FA} FA_{ri} + \delta_{FD} FD_{ri} \quad (3.8)$$

where $MARSTAT_i$ is the Marital Status of farmer, AGE_i is the age of farmer, HHS_i is the household size, EXP_i is experience in farming, GEN_i is gender of farmer, $EDUCYrs_i$ is the number of years of education of the farmer, $EXPSoy_i$ is farmer experience in soybean farming, and $EXTNum_i$ is number visits by extension officers. The inefficiency model captures agglomeration externalities (FA and FD) to determine the effects of agglomeration on the efficiency of soybean farms.

3.4.6 Variables to Assess Technical Efficiency

For the efficiency variables, *a priori* expectations for farmer experience (EXP), soybean farming experience (EXPSoy), age of farmer (AGE), number of extension agent visits to soybean farms (EXTNum) and farmer's educational level (EDUCYrs) are expected to have a positive relationship with technical efficiency (Table 3.2).

Efficiency variables such as marital status of the farmer (MARSTAT), gender of the farmer (GEN) and the household size of the farmer (HHS) are expected to either have a negative or positive relationship with efficiency depending on the economic dynamics present in the soybean sector. MARSTAT represents the marital status of the farmer captured as a dummy variable to determine its effect on the efficiency of the farmer.

Table 3.5: Productivity variables, description, unit of measurement and a priori expectations

Variable	Description	Unit of measurement	<i>A priori</i> expectation
Y	OUTPUT	Kg	
Inefficiency Variables:			
MARSTAT	Marital Status	Dummy: 1 = Yes 0 = No	+/-
EXP	Experience in farming	Years	+
EXPSoy	Experience in soybean farming	Years	+
AGE	Age	Years	+
GEN	Gender	Dummy: 1 = Male 0 = Female	+/-
EXTNum	Extension (number of visits)	Number	+
HHS	Household Size	Number	+/-
EDUCYrs	Education	Years	+
FD	Farm Density	Number of farms/sq. km	+/-
FA	Farmer Association	Dummy: 1 = Yes 0 = No	+/-

Source: Survey, 2017

EXP and EXPSoy are inefficiency variables capturing experience in farming and experience in soybean farming, respectively, measured in years. Age of the farmer, measured in years, is expected to have a positive relationship with efficiency. The EXTnum variable represents number of times that extension agents visit soybean farmers. This is a measure of the frequency (or intensity) of farmer interactions with extension agents. GEN represents the gender of the farmer and is captured as a dummy variable with 1 and 0 representing male and female respectively. A positive relationship between GEN and efficiency will indicate that males are more efficient and vice-versa. The study also considered household size (HHS) as a relevant explanatory variable in the inefficiency model. It is captured as the number of people (adults and children) that are in the household.

As is in the case of productivity estimation, the study expects that agglomeration externalities (captured by FA and FD) influence the efficiency of soybean farms.

3.4.7 Elasticities

The translog stochastic production function in equation 3.7 shows elasticity parameters (β_1 to β_6) which represent the output elasticities of the various inputs (SEED, K, LAB, FERT) as well as the agglomeration indexes FA and FD. In the model, the output elasticities are functions of the various inputs used. The first-order coefficient is interpreted as elasticities of the output with respect to the inputs used when we normalize the input and output variables by their respective means (Onumah *et al.*, 2010). The sum of the elasticities is the returns to scale or the estimated scale elasticity (ϵ). Returns to scale is the percentage change in output resulting from a percentage change in all the input factors. The estimated scale elasticity for the industry demonstrates either increasing returns to scale ($\epsilon > 1$), decreasing returns to scale ($\epsilon < 1$) or constant returns to scale ($\epsilon = 1$).

3.4.8 Hypotheses Tests for Model Specifications and Statistical Assumption Using the Likelihood-Ratio (L-R) Test

The main test of the study is that increased levels of knowledge and information spillovers could reduce the errors made in decision-making and this could lead to more technically efficient and productive soybean farming. This is evidenced by the elasticities associated with the output variable estimates for both the production frontier and efficiency models.

The study investigates some hypotheses tests for model specifications (Table 3.3) employing the generalized likelihood ratio test, the statistic specified as:

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

where $L(H_1)$ and $L(H_0)$ represent the values of likelihood function under the alternative and null hypotheses respectively (Onumah *et al.*, 2010). LR has an approximate Chi-square or mixed Chi-square distribution and this is conditional on the null hypothesis being true with a degree of freedom equal to the number of parameters assumed to be zero in the null hypothesis (Coelli, 1995).

The hypothesis test is carried out to determine whether the functional form adopted for the data, which is the stochastic frontier model, is the best suited representation of the data, especially in comparison to the Cobb-Douglas functional form, and whether the conventional and exogenous input variables in the efficiency model can explain the technical efficiency (Coelli, 1995; Etwire *et al.*, 2013). These tests are necessitated by the distributions in the error term.

The hypotheses to be tested include the following:

1. The test hypothesizes that the stochastic frontier model is better suited for the data analysis. The null hypothesis is that the Cobb-Douglas production function is the best fit for the data.
2. The null hypothesis is that inefficiency effects are absent from the model at every level. The alternative hypothesis is that there are inefficiency effects within the production function at every stage.
3. The null hypothesis is that inefficiency effects are non-stochastic, contrary to *a priori* expectations of stochasticity in the inefficiency. Conversely, the alternative hypothesis states that inefficiency effects are stochastic.
4. The null hypothesis is that the simpler half-normal distribution adequately represents the data, given the specifications of the generalized truncated-normal model. The alternative hypothesis is that the simpler half-normal distribution does not adequately represent the data.

5. Specific farm factors are hypothesized to influence inefficiency, however the null hypothesis states that inefficiency is not influenced by the farm factors.
6. The null hypothesis is that agglomeration externalities (FA and FD) have no effect on efficiency and productivity. The alternative hypothesis is that FA and FD influence efficiency and productivity.

Table 3.6: Tests of hypotheses for model specifications and statistical assumptions

Null Hypothesis	Alternative hypothesis
$H_0: \beta_{ij} = 0$	$H_A: \beta_{ij} \neq 0$
$H_0: \gamma = \delta_0 = \delta_1 = \dots = \delta_{10} = 0$	$H_A: \gamma \neq \delta_0 \neq \delta_1 \neq \dots \neq \delta_{10} \neq 0$
$H_0: \gamma = 0$	$H_A: \gamma \neq 0$
$H_0: \delta_0 = \delta_1 = \delta_2 = \dots = \delta_{10} = 0$	$H_A: \delta_0 \neq \delta_1 \neq \delta_2 \neq \dots \neq \delta_{10} \neq 0$
$H_0: \delta_1 = \delta_2 = \dots = \delta_{10} = 0$	$H_A: \delta_1 \neq \delta_2 \neq \dots \neq \delta_{10} \neq 0$
$H_0: \delta_9 = \delta_{10} = 0$	$H_A: \delta_9 \neq \delta_{10} \neq 0$

Source: Adapted from Onumah et al., 2010.

The Ox-SFAMB version 3.40 software was used to obtain the MLEs for the different parameters and was also used to analyze the socio-economic and demographic characteristics of the soybean farmers.

3.5 Sample Size, Sampling Procedure and Data Collection

Data was collected from 400 farmers, 200 each from the Upper East Region and Upper West Region of Ghana. The sample size after data cleaning was 393 farmers; 196 from the Upper East and 197 from the Upper West Regions. Of the 393, 200 are farmers who belong to farmer groups or cooperatives (FA) and the remaining 193 do not (non-FA).

A multistage sampling method was employed in the selection of the study areas. The Upper East and Upper West regions were purposively selected for their vibrancy in soybean production, as they are located within the savannah belt where soybean thrives best in Ghana (MoFA, 2011). The districts within which the towns for the research were sampled from were also purposively selected, the decision and choice informed and influenced by MoFA, USAID and MEDA who have carried out extensive work on soybean in these areas; Lawra and Wa West districts from the Upper West Region, Bongo and Garu-Tempane districts from the Upper East Region.

Finally, the simple random sampling method was used to select the towns for the study. Through the lottery method, four communities from the districts were selected from a list of communities that are vibrant in soybean production.

Questions pertaining to productivity, efficiency, socio-economic characteristics and other relevant aspects of the study were asked farmers through questionnaires. These well-structured questionnaires were issued as part of the survey and contained questions which tried to tease out relevant information concerning the soybean farmers and their farming activities. The aim was to elicit information relevant to the research. The questionnaires were administered to soybean farmers in some selected communities within the four districts chosen for the study.

3.6 Study Areas

As mentioned earlier, the study area was the Upper East and Upper West Regions of northern Ghana. These regions were selected for their vibrancy in soybean farming and production. Data was collected from four communities within four districts from the two regions (Lawra in the Lawra district, Nyoli in the Wa West district, Gambrungu in the Bongo district and Konkomada in the Garu-Tempane district).

3.6.1 Location and Size of the Study Area

The Lawra and Wa West districts are situated in the Upper West Region of Ghana, and Bongo and Garu-Tempene in the Upper East Region of Ghana. The Lawra district is situated in the north-western part of the Upper East Region, and is bordered to the north and to the east by the Nandom and Lambussie districts, respectively, and to the south-west and west, by Burkina Faso (GSS, 2013). The Wa West district is situated in the western part of the Upper West Region and shares borders with the Northern Region, on the south, Nadowli district, on the north-west, Wa on the east and Burkina Faso on the west. Figure 3.2 presents a map of the study area.

The Bongo and Garu-Tempene districts are both located within the south-eastern part of the Upper East Region. The Bongo district shares boundaries with Burkina Faso, Kassena-Nankana East Bolgatanga and Nabdum district to the north, west, south-west and south-east respectively, while the Garu-Tempene district shares boundaries with Bawku, Bunkpurugu-Yunyoo district, Bawku West district and Togo to the east.

Lawra and Wa West districts have a total land size area of about 527.32 and 1492 square kilometres respectively, while Bongo and Garu-Tempene districts have respective land size areas of about 495.5 and 1060.91 square kilometres (GSS, 2013).

The four districts lie within the Guinea and Sahel Savannah grassland zone which provide favourable and conducive ecological variables that make it conducive to grow cereal crops such as soybean, millet, maize, groundnuts, cowpea, among others.

Figure 3.2: Map of the Study Areas in National Context



Source: Mapsof.net, 2017.

3.6.2 Demographic Characteristics and Agriculture Participation

The four districts are made up predominantly of farmers, and especially subsistence farmers who grow their crops primarily to feed their families. Statistics show that there are a lot more women

crop farmers (GSS, 2013) and this is probably one of the contributing factors to the springing up of multiple initiatives to help empower women, mostly financially, to increase their productivity.

In the Lawra district, about 83.5 percent of households are engaged either directly or indirectly in agriculture with about 96.4 percent of this number engaged in crop farming (GSS, 2013). For the Wa West district, located in the same region as the Lawra district, the population is made up of at least 91.6 percent agricultural households, that is households that have at least one member engaged in agricultural activities (GSS, 2012). About 97.2 percent of this number are into crop farming which they either do in conjunction with or without animal rearing.

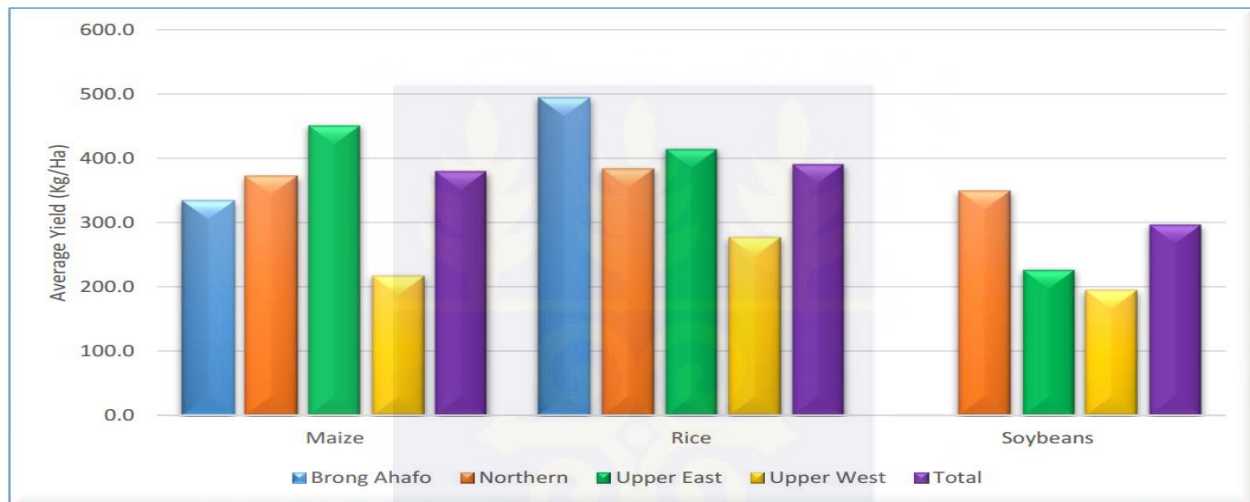
The Bongo and Garu-Tempene districts recorded very high agriculture participation among the households, recording as high as 95.7 percent and 95.4 percent respectively with the percentage of these figures that are into crop farming being about 98.8 percent for both districts (GSS, 2013). The proportion of agricultural households that are into crop farming in the Upper East and Upper West regions grow a number of staple crops, especially cereals, in large commercial quantities, with soybean being one of such crops that farmers attach great importance to.

3.6.3 Soybean Farming in the Upper East and Upper West Regions

Soybean is considered one of the most viable crops in the three northern regions of Ghana due to the conduciveness of the ecology and the built-up resistance of soybean and other cereal crops to pests and diseases that exist and are likely to occur in these areas. Of all the regions in Ghana, the Northern Region, Upper East Region and Upper West Region have the highest yield of soybean, with the Upper West and Upper East Regions being marked as having the potential to increase yields exponentially (Amanor-Boadu *et al.*, 2015; Zereyesus *et al.*, 2012). Compared to rice and maize, researchers and scientists believe that soybean has great potential of having huge economic value, in addition to its nutritional value (Mbanya, 2011).

According to Amanor-Boadu *et al.* (2015), the average yield for soybean was lowest in the Upper West Region with average yields of about 194 Kg/Ha as against average nationwide soybean yields of 296 Kg/Ha. Juxtaposing it with average maize and rice yields of 380 Kg/Ha and 399 Kg/Ha respectively, there is a lot more effort that needs to be put into the soybean sector to boost production levels (Figure 3.3).

Figure 4.3: Average yield by crop and Region (Kg/Ha)



Source: Amanor-Boadu *et al.*, 2015.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and discusses the results of the study. These include an assessment of the socio-economic characteristics of soybean farmers, taking into consideration the proportion of these farmers that belong to farmer associations and otherwise. The chapter also looks at and discusses parameter estimates for the stochastic frontier and the efficiency models, and provides statistics for the efficiency levels of the farmers. There is also a discussion of the effects of agglomeration externalities on the production frontier and on technical efficiency of soybean farms.

4.2 Socio-Economic Characteristics of Soybean Farmers

Of the 393 farmers interviewed, 196 are from the Upper East Region and 197 from the Upper West Region. 193 (49.1%) belong to farmer associations and 200 (50.9%) do not belong to any farmer association and so ply their farming activities independent of any farmer groups.

The respondent farmers were made up of 148 male and 245 female farmers. Females seem to participate more in soybean farming partly because it is considered as a crop mainly grown by women and also because of the many interventions that have provided aid to women vis-à-vis soybean production (MEDA, 2017) creating an incentive for women-participation and involvement.

The majority of the farmers are married (76%) confirming the findings of Etwire *et al.* (2013) and Okpachu *et al.* (2014) that marriage among farmers in Northern Ghana is high and this so not only because it is an important social obligation, but also because it provides a source of family labour and an opportunity for women farmers to own lands.

The majority of the farmers are Muslims (81.8%) and a high proportion of them have had little or no formal education which is a farmer demographic that is typical of the farming landscape in Ghana, as described in the GLSS 6 (GSS, 2014). Only one farmer (0.5%) had had tertiary education, again confirming low levels of education among farmers (Table 4.1). Results from Table 4.2 reveal that the average number of years spent in formal education by the farmers is 1.9 years; this is quite low. The means are lower than the mean number of years of education of 2.3 years as estimated by Mohammed *et al.* (2016) for farmers in the Northern Region of Ghana.

Etwire *et al.* (2013) explain that farm households consider formal education as uncomplimentary to farming and so deem it as a threat to their farming activities. This dynamic can be inimical to the adoption of new farming techniques and seed varieties as some appreciable level of education is needed to facilitate this.

The mean age of the farmers is 41.82. Incidentally, a study carried out by Mohammed *et al.* in 2016 gives the average age of soybean farmers in northern Ghana as 39 years, indicating that the sector is mostly dominated by middle-aged farmers. Etwire *et al.* (2013) state average ages of male and female farmers as 44 percent and 36 percent respectively, explaining that this implies that current soybean farmers may still be able to actively cultivate the crop for the next two or three decades. The average household size of the farmers was 7.67. The household comprises adult males and females, and children not yet 18 years old. Table 4.2 shows that the mean number of adult males, adult females and children per household are 1.48, 2.14 and 3.82 respectively.

Table 4.4: Frequency distribution of socio-economic demographics and variables in the efficiency model

Characteristics	Frequency	Percentage (%)
Location (Region):		
Upper West	197	50.1
Upper East	196	49.9
Gender:		
Male	148	37.7
Female	245	62.3
Marital Status:		
Single	29	7.4
Married	301	76.6
Divorced	61	15.5
Widowed	2	0.5
Religion:		
Christian	69	17.7
Muslim	318	81.8
Traditionalist	2	0.5
Level of education:		
No schooling	287	73.0
Primary	72	18.3
JHS	24	6.1
SHS	9	2.3
Tertiary	1	0.3
FA farmers	193	49.1
Non-FA farmers	200	50.9

Source: Survey data, 2017

The average number of years of general farming (years of experience in the farming sector) was 6.97. The study also tried to ascertain the number of years of soybean farming by the farmers, recording mean years of experience in soybean farming as 4.88. This is an adequate amount of experience and should have positive implications on their output since they understand better the intricacies of farming (Okpachu *et al.*, 2014).

Table 4.5: Summary statistics of other socio-economic variables of the samples

Variables	Minimum	Maximum	Mean	Std. Dev.
Age	19	65	41.82	9.215
Education (number of years spent to attain educational level)	0	18	1.8931	3.5397
Household size	1	16	7.67	5.929
Number of adult males in the household	0	8	1.48	0.818
Number of adult females in the household	1	8	2.14	1.207
Number of children (below 18) in the household	0	12	3.82	2.093
Farming experience (Years)	1	22	6.97	4.528
Soybean farming experience (Years)	1	21	4.88	37.0
Extension agent visits	0	5	2.3	0.888

Source: Survey data, 2017

About 77.85 percent of the farmers received extension services during the 2016 farming season while 22.15 percent did not have any interaction with extension officers. The mean number of times farmers were visited by extension agents was 2.3. The more interactions farmers have with extension agents, the more they are able to access advice related to farming practices, input and market information (Associates for Change, 2012).

4.3 Analysis of Agglomeration Externalities

Analyses were carried out on the data collected, to ascertain the agglomeration externalities. The analysis show that of the 393 farmers interviewed, 193 (49.1%) belong to farmer associations such as Farmer Based Organizations, cooperatives, groups set up by NGOs or the farmers themselves, among others. Two hundred (50.9%) of the farmers do not belong to any farmer agglomerate and operate their farming activities as independent farmers (Table 4.3).

Table 4.6: FA and Non-FA farmer proportions

Farmer categorization	Frequency	Percentage (%)
FA Farmers	193	49.1
Non-FA farmers	200	50.9

Source: Survey data, 2017.

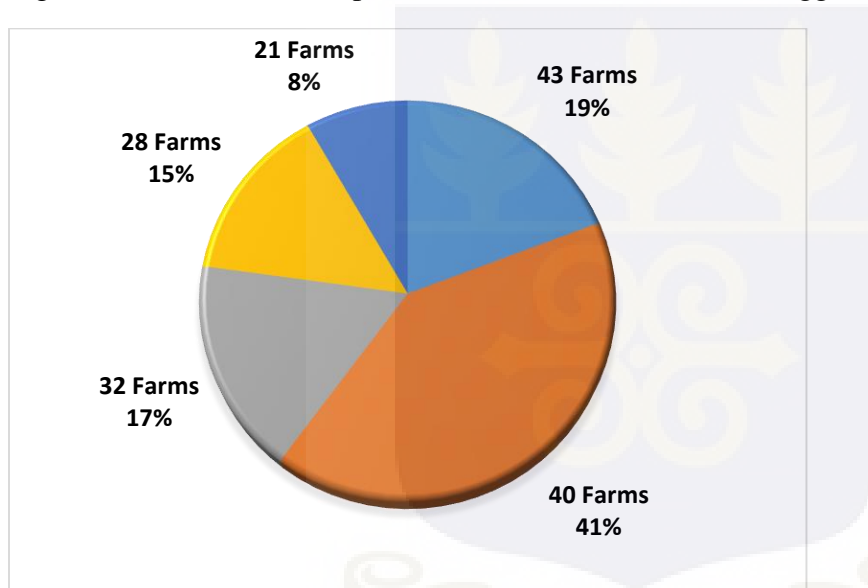
Farmers who form or join farmer groups would usually do so to pull together ideas, for reasons of synergy and other positive agglomeration externalities that culminate from like-mindedness (Etwire *et al.*, 2013; Battese and Tveteras, 2006). They would also form groups to improve the economies of scale. Battese and Tveteras (2006) found that the formation of groups, leading to increased industry sizes, leads to increases in output and efficiency. It is therefore not very encouraging the current statistic of soybean farmers who belong to farmer groups or associations.

The study also sought to identify the farm densities within the farmer agglomerates, based on the location and proximity of farms to each other. Following Battese and Tveteras (2006), there is an assertion that farm density is closely linked with the sharing of industry infrastructure among farmers who locate their close to each other, and that opportunities arise to exploit external economies of scale towards increasing productivity and efficiency. Identifying these farm densities was carried out only for farmers who belong to farmer associations. The results of the analysis

identified 5 categories of farm densities among the 193 soybean farms that belong to farmers in farmer associations. The parameter, Farm Density (FD), was measured by the number of farms within a square kilometre.

The analysis identified Farm Densities of 21 farms, 43 farms, 40 farms, 32 farms and 28 farms; 8 percent, 19 percent, 41 percent, 17 percent and 15 percent of the FA farms belonged respectively to these FDs (Figure 4.1).

Figure 4.3: Farm densities per kilometre within farm/farmer agglomerates



Source: Survey data, 2017.

The greater the farm density, the greater the agglomeration externalities (Battese and Tveteras, 2006) and the stronger the agglomeration economy that is established (de Vor and de Groot, 2008). As such, farm densities of 43 and 40 farms should have higher levels of agglomeration externalities such as knowledge spillovers than farms belonging to lower farm densities due to increased frequencies of interactions between farmers and also lobbying opportunities that are made available to these farmers due to their size (de Vor and de Groot, 2008).

4.4 Agglomeration Externalities

There are externalities that arise from agglomeration economies created as a result of locating farms closer to each other and to their client base. Firms, including farmer associations, are more likely to experience these externalities than those who do not belong to farmer agglomerates (Robins, 2011). According to the World Bank (2009), the concentrations that arise from economic production of any kind have some compatibility with geographic convergence in the living standards of the people. It is also compatible with market forces of agglomeration and specialization and this can lead to better standards of living for participants.

These externalities arise and become more impactful through interactions between farmers and between farmers and other sources of influence (de Vor and de Groot, 2008). This can be facilitated through regular meetings.

The findings from Table 4.4 reveal that the majority of FA farmers (88.6%) listed knowledge on farming techniques as the most impactful positive externality arising from belonging to farmer associations. They also recognized advice on soybean farming (83.4%) and information on labour and access to an available labour pool (71.5%) as very key agglomeration externalities. This is in line with the findings of Duranton and Puga (2004) that the most significant sources of agglomeration externalities include labour supply, demand matching and knowledge spillovers. About 68.9 percent alluded to infrastructure development being a merit of agglomeration (Table 4.4).

The farmers also identified some negative externalities that arise from farmer agglomerations. In their paper, Larue and Latruffe (2008) state that negative externalities need to be considered in the analysis of the effects of agglomeration externalities. The negative externality ranked highest by

the farmers is the unfavourable competition (62.7%) that arises as a result of proximity to each other and belonging to close knit farmer groups.

Other negative externalities that the findings of the study revealed are problems of water shortage due to pressure exertions on limited water sources by large groups of farmers, and rising incidence of water pollution. Other negative consequences of agglomeration were identified by farmers as theft and incidence of crop pests and diseases (Table 4.4).

Table 4.4: Agglomeration externalities in the soybean sector

Agglomeration externality	Percentage (%)
<i>Positive Externalities:</i>	
Knowledge on soybean farming techniques	88.6
Advice on soybean farming	83.4
Information on and access to labour (labour pooling)	71.5
Industry infrastructure	68.9
<i>Negative Externalities:</i>	
Unfavourable competition	62.7
Water unavailability	57
Water pollution	50.3
Theft	32.6
Incidence of crop pests	27.5
Incidence of crop diseases	17.1

Source: Survey data, 2017

4.5 Descriptive Findings of Frontier Model Variables

Productivity of the farmers was a key focus of this study. The study investigated productivity issues arising from outputs that are churned out per unit input used in the soybean sector. The

results of the analysis revealed some estimates for output and input variables for both FA and non-FA farmers.

The output of the farmers for the 2016 season was computed at an average of 354 kilograms. The quantity of seed used by soybean farmers ranged from a minimum of 0.9 Kg/Ha to 54 Kg/Ha. The findings recorded that mean seed quantities planted by farmers is 9.45 kilograms. This is below the mean seed quantity of 12.7 kilograms applied per hectare as revealed by Mohammed *et al.* (2016) for soybean farming in the Northern Region of Ghana.

Mean quantities used of inoculant, weedicide and compost were 25.45 kilograms, 15.15 kilograms and 59.05 kilograms respectively (Table 4.5). Mean amounts of weedicides used per season confirm the findings of Mohammed *et al.* (2016) of 15.2 kilograms per hectare.

Mean amounts of labour employed by soybean farmers was 30.75 person-days (Table 4.5). Compared to the situation in Vietnam, which is one of the highest producers of soybean in the world, Khai and Yabe (2013) reveal a mean of 57.03 person-days leading to average output levels of 1,788.76 kilograms for the 2012 soybean farming season. The mean number of person-days employed per farm for the Northern Region is 41.4 (Mohammed *et al.*, 2016).

From the findings of the study, the average farm size is 0.4 hectares with farm sizes ranging from 0.04 to 2.43 hectares for soybean farmers in both the Upper East and Upper West Regions (Table 4.5). The findings of Etwire *et al.* (2013) of mean farm sizes of 0.4 for soybean farms in the Northern Region show that farm sizes are about the same across the three northern regions of Ghana, averaging about 0.4 hectares per soybean farmer.

Table 4.5: Summary statistics on productivity estimates of soybean farmers

Variables	Minimum	Maximum	Mean	Std. Dev.
Output (Kg)	60	800	354	154.655
Seed quantity (Kg)	0.9	54	9.45	6.87
Inoculant (Kg)	0	100	25.45	3.5397
Weedicides/herbicides (litres)	0	60	15.15	12.155
Compost (Kg)	0	500	59.05	109.855
Labour (person-days)	6	60	30.75	14.3
Farm size (Ha)	0.04	2.43	0.4	0.305

Source: Survey data, 2017

4.6 Hypotheses Tests for Model Specification and Statistical Assumption

The results of the hypotheses tests are presented in Table 4.6. They show that the first null hypothesis that states the Cobb-Douglas function is an adequate representation for the data (by stating that the coefficients of the second-order variables add up to zero) is rejected. The translog stochastic function is better suited to the data. The null hypothesis stating that inefficiency effects are not stochastic is also rejected. The null hypothesis for the third test is also rejected showing therefore that the Ordinary Least Square function is not the best model of estimation for the data. For the fourth hypothesis, the null hypothesis is rejected for the alternative; the intercepts and coefficients associated with the efficiency model do not add up to zero. This shows that inefficiency variables influence technical efficiency.

Table 4.6: Hypotheses tests for model specification

Null hypothesis	Log-likelihood value	Test statistics (λ)	Critical value ($\lambda_{0.001}^2$)	Decision
$H_0: \beta_{ij} = 0$	26.42	22.80	18.47	Reject H_0
$H_0: \gamma = \delta_0 = \delta_1 = \dots = \delta_{10} = 0$	50.69	38.23 ^a	20.52	Reject H_0
$H_0: \gamma = 0$	275.62	35.44 ^a	10.83	Reject H_0
$H_0: \delta_0 = \delta_1 = \delta_2 = \dots = \delta_{10} = 0$	50.70	48.55	22.46	Reject H_0
$H_0: \delta_1 = \delta_2 = \dots = \delta_{10} = 0$	50.56	48.28	20.52	Reject H_0
$H_0: \delta_9 = \delta_{10} = 0$	251.13	32.15	16.71	Reject H_0

^a Values of test of one-sided error from the Ox output.

The fifth hypothesis that assumes all coefficients in the inefficiency model (with the exception of the constant term) are zero is also rejected. This shows that the collective effects of factors of farm inefficiency play a significant role in explaining variations in the soybean sector. The sixth hypothesis is the test of FA and FD. The coefficients of FA and FD in the efficiency model do not add up to zero and so the null hypothesis is rejected.

4.7 Productivity Estimates of the Stochastic Frontier

Table 4.7 presents Maximum-Likelihood Estimates (MLE) of the stochastic frontier translog model. The complete table is presented in Appendix C. The coefficients of the input variables are explained as elasticities to describe the production of soybean vis-à-vis the individual inputs of production (Table 4.7).

Results show positive coefficients for all the input variables, including those of the agglomeration variables, FA and FD. They are all statistically significant indicating significant effect of the input variables on soybean production in the Upper East and Upper West Regions of Ghana.

Table 4.7 shows that output elasticities for the input variables SEED, CAPITAL, LABOUR and FERT have positive significant coefficients indicating influence of statistical significance on the dependent variable; productivity. A percentage increase in seed-use, capital, labour and fertilizer-use (inoculant-use) will increase soybean output by 0.14 percent, 0.14 percent, 0.28 percent and 0.41 percent respectively. With an output elasticity of 0.41, inoculant (captured by FERT) is the most important input among the four conventional input variables and thus has the highest impact on productivity. Labour is the second most important input in terms of the frontier output elasticity with a value of 0.28 indicating significant impact on the production frontier.

FA and FD show a positive relationship with productivity, statistically significant at 5 percent and 10 percent respectively. The elasticity of frontier output with respect to FA and FD are 1.02 and 0.03 indicating that FA (farmers belonging to groups), which is an indicator of the size of industry, has the greatest effect on the production frontier. This is in line with findings by Battese and Tveteras (2006) for the effect of FA/industry size on productivity. An increase in FA and FD by 1 percent will lead to respective increases of 1.02 percent and 0.03 percent in the output. Thus an increase in the number of farmers forming or joining agglomerates and an increase in the number of farms per square kilometer will lead to increases in output.

The positive elasticities associated with FD and FA show that there are positive externalities associated with farm density and farmer associations and these are statistically significant. The sum of the output elasticities is 0.98 indicating diminishing returns to scale (Table 4.7). This result corroborates the findings of Mohammed *et al.* (2016) for the soybean sector in the Northern Region. They report returns to scale of 0.79 indicating diminishing returns to scale. This means therefore that if input factors are increased by the same proportion, the increase in output will be less than proportionate to increases in the input variables. Therefore, if the soybean sector in the

two regions increases all of its factor inputs by 1 percent, soybean production would increase by 0.98 percent. Farmers are therefore better off when they reduce their output levels.

Table 4.7: Estimates of the stochastic frontier model (Productivity estimates)

	Coefficient	p - values
Constant	0.386389**	0.017
LnSEED	0.139101***	0.000
LnK	0.141429***	0.001
LnLAB	0.282621***	0.000
LnFERT	0.413061***	0.000
FD	0.0276757**	0.025
FA	1.022346*	0.086
RTS	0.98	

***, **, * indicate significance at 1%, 5% and 10% respectively

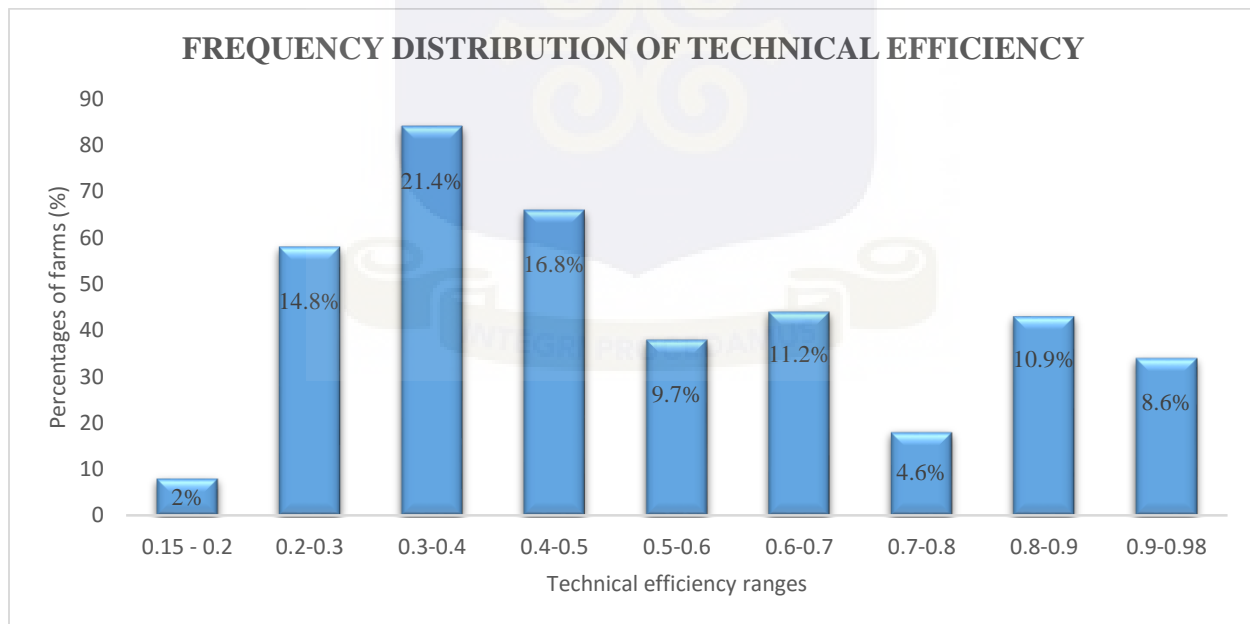
4.8 Technical Efficiency Estimate Scores

The results of the analysis show that technical efficiencies for soybean farms in the Upper East and Upper West Regions range from 0.15 to 0.99 (Figure 4.2). This conforms to the findings of Etwire *et al.* (2013) which gave a technical efficiency range of between 0.11 and 0.99 for soybean farms in the Northern Region. This wide variation in technical efficiency scores indicates the presence of varying levels of resource utilization among soybean farmers. Diverse managerial and decision-making patterns also contribute to the vast differences in the efficiency scores across soybean farms in the two regions. The soybean sector thus demonstrates an uneven distribution of farmers across different technical efficiency scores. About 35.3 percent of the soybean farms operate at efficiency levels of 60 percent and above with about 19.5 percent operating above efficiency levels of 80 percent. This group can be said to be the most technical efficient in the

sector. An estimated 55 percent of the soybean farms, being the least efficient, were found to be operating at efficiency levels of below 50 percent.

The mean technical efficiency index for soybean farms is estimated at 0.52 (Figure 4.2) indicating about 52 percent efficiency. This shows that averagely, soybean farmers produced 52 percent of the potential (stochastic) frontier output and fell short of the frontier by 0.48 points. Therefore, given the technology and input levels available to soybean farmers, 48 percent of technical potential output is not realized. There is therefore about 48 percent room for improvement for the average soybean farmer to increase their output while maintaining current levels of technology and input-use. Etwire *et al.* (2013) and Mohammed *et al.* (2016) report mean efficiency levels of 53 percent and 54.2 percent respectively for soybean farms in Northern Ghana.

Figure 4.4: Technical efficiency scores of soybean farmers



Source: Survey data computations, 2017.

The results indicate comparatively high inefficiency in soybean production in the Northern part of Ghana, especially in the Upper East and Upper West Regions. The high inefficiency levels could

be as a result of non-farm employment, inadequate education, farm experience and degree of specialization (Olayiwola, 2013).

Olayiwola (2013) reports a mean efficiency score of 87 percent for smallholder soybean farms in Nigeria indicating a comparatively higher technical efficiency score statistic in the soybean sector in Nigeria.

There is considerable potential for improving the productivity of soybean farms given the current inputs and technology available. This will enable the farmers to reduce costs of production and increase their output levels.

4.9 Determinants of Technical Efficiency

The study examined the determinants of technical efficiency in the soybean sector to establish a basis for informing policy on the actions to be taken to improve on the technical efficiency of the farmers. Table 4.8 presents the coefficients of the inefficiency variables. The signs and significance of the parameter estimates have implications for policy concerns. A positive estimate indicates a positive impact on the level of technical inefficiency.

The results show positive statistically significant coefficients for Age of farmer, Gender and FA. This shows that older farmers are less technically efficient than younger ones and this could be as a result of younger farmers having more progressive attitudes to new technologies and farming innovations (Onumah *et al.*, 2010). The findings are in line with those of Coelli and Battese (1996) that explained that this occurrence could be due to the conservative nature of older males and their unwillingness to adopt new technology. These findings are also in line with those of Onumah *et al.* (2010) and Shaheen *et al.* (2011) whose findings of fish farmers and cauliflower growers respectively revealed that younger farmers are more technically efficient than older farmers.

Table 4.8: Efficiency model estimates

	Coefficient	p - values
Constant	0.150335	0.695
MARSTAT	0.201916	0.124
EXP	-0.0182781	0.255
EXPSoy	-0.0125825	0.630
AGE	0.00987458*	0.088
GEN	0.356142**	0.013
EXTNum	-0.0871227*	0.094
HHS	-0.0226126	0.238
EDUCYrs	0.00871641	0.484
FA	5.97356*	0.074
FD	-0.276019*	0.097

Source: Analysis of survey data, 2017.

**, * indicate significance at 5% and 10% respectively

A positive coefficient for the gender dummy is positively significant indicating therefore that female farmers are more technically efficient than male farmers. This confirms the findings of Mohammed *et al.* (2016) and could be as a result of the many initiatives spearheaded by NGOs and government to empower women farmers (MEDA, 2017) by providing them with inputs and other resources.

The coefficient of the variables EXTNum (Number of extension agent visits) and HHS (Household size) were negative with the coefficient of EXTNum being statistically so. This means therefore that an increase in the frequency of farmer-extension agent interactions leads to higher efficiency of farmers. Farmers who interact more with extension agents are therefore more efficient than farmers who do not interact with them as much. Perhaps this is so because new methods and

technologies of farming are introduced to the farmers and the more regular these interactions, the better the rate of adoption. The findings of Dhebibi *et al.* (2007) and Ogundari (2013) conform to the findings of this study and explain that as extension agents serve as a link between farmers and researchers, they are conduits through which new innovations in farming methods are introduced to farmers.

The coefficient of FD is significantly negative indicating therefore that farm concentration is positively related to technical efficiency. Hence, increase in farm density leads to increase in technical efficiency. This conforms to the findings of Battese and Tveteras (2006) whose findings confirmed *a priori* expectations of increase in technical efficiency with increase in farm density. This is as a result of the positive externalities that arise from farm proximity to each other, such as input-sharing that are likely to lead to reduction in cost, knowledge and information spillovers that may inform farmers on more efficient methods of production.

The coefficient of FA is significantly positive suggesting that farmers who belong to farmer associations tend to be less efficient than those who do not. This is in contrast with the findings of Battese and Tveteras (2006) whose findings revealed that industry size (captured as FA in this study) has a positive influence on efficiency. The findings of this study with respect to the effects of FA could be due to farmers not utilizing efficiently the opportunities that are presented them by virtue of them belonging to groups. For example, time wasted chatting or pursuing other non-profitable ventures could tell negatively on their efficiency. The result could also mean that the negative externalities that arise from farmer agglomeration could be accounting for these results. These could include the dissemination of harmful advice or information pertaining to farmers' methods of farming (Battese and Tveteras, 2006) and this could influence negatively their methods of farming.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a summary of and conclusions on the findings of the study. It also includes some recommendations based on the findings of the study as well as on literature reviewed with respect to these findings.

5.2 Summary and Major Findings

The study set out determine the agglomeration externalities, productivity and technical efficiency of soybean farms in the Upper East and Upper West Regions of Ghana. It sought to achieve this by identifying the agglomeration externalities that exist in Ghana's soybean sector, by estimating the output elasticities with respect to input-use, by determining the technical efficiency levels in the soybean sector and also by analyzing the effect of agglomeration externalities on productivity and efficiency of soybean farms.

The study adopted the stochastic frontier and technical efficiency models to help achieve its objectives. Both the frontier and efficiency models were specified to include the agglomeration indexes FA and FD to determine the effect of agglomeration externalities on productivity and technical efficiency. A technical efficiency model was also specified to determine the technical efficiency levels of soybean farmers in the two regions of study.

Data used for the analysis was on 393 soybean farmers made up of 84 male and 109 female soybean farmers. 193 of the farmers belong to farmer associations while 200 are independent farmers.

The Ox-SFAMB software was used in the analysis to determine the output elasticities with respect to input-use, to estimate the efficiency levels and to estimate the coefficients of efficiency.

Hypotheses tests were carried out to test the validity of the translog stochastic model as the best suited for the analysis of the data. The results showed that the translog model is a better fit for the data than the Cobb-Douglas or Ordinary Least Squares functions. The hypotheses test also showed that the coefficients of the efficiency model do not add up to zero, thus the variables modeled in the efficiency model are appropriate for the measurement of their effects on technical efficiency.

Two indexes, FA and FD, were modeled into the productivity and technical efficiency to represent agglomeration externalities. These indexes served as proxies for agglomeration externalities, FA representing industry size (Number of farmers who belong to farmer associations or groups) and FD representing farm density, measured by the number of farms per square kilometre. The results of the analysis showed that for the stochastic frontier model, agglomeration externalities had significantly positive coefficients. This indicates that agglomeration externalities have significant impact on productivity. Of the two indexes however, FA was seen to have the greatest impact on the production frontier as it had the higher elasticity (1.02) of the two indexes.

The input variables seed, capital, labour and fertilizer (inoculant) have significant positive effect on productivity. The results of the Maximum-Likelihood Estimates of the stochastic frontier translog model show that a percentage increase in seed, capital, labour and fertilizer will increase the soybean production frontier by 0.14 percent, 0.14 percent, 0.28 percent and 0.41 percent with fertilizer having the biggest effect on the frontier.

The soybean sector exhibits diminishing returns to scale. A proportionate increase of 1 percent in the input factors will lead to a less than proportionate increase of 0.98 percent in output.

The estimates of the technical efficiency scores show that technical efficiencies in the soybean sector range from 0.15 to 0.99 indicating a wide variation in technical efficiency levels across the

sector. Approximately 55 percent of the soybean farms operate at efficiency levels below 50 percent with about 19.5 percent operating above efficiency levels of 80 percent. The mean technical efficiency index for the soybean farms in the Upper East and Upper West Regions was estimated at 0.52 indicating about 52 percent efficiency in the sector.

The study examined the determinants of technical efficiency in the soybean sector by modeling efficiency variables into a technical efficiency model. The results showed that age and gender of the farmer have significantly negative coefficients indicating that technical efficiency decreases with age of the farmer and female farmers are more efficient than their male counterparts. Younger farmers have a more progressive attitude towards the adoption of new innovations as compared to their relatively more conservative older counterparts. The results also indicate that female farmers are more technically efficient than male farmers. *A priori* expectations for gender of the farmer with respect to technical efficiency were that the results could be in favour of either male or female farmers. The results however show that there is a significant difference in the efficiency of female and male soybean farmers implying that female farmers are able to combine available input resources more efficiently to produce higher output levels.

Frequency of farmer-extension agent interactions was found to have a positive relationship with efficiency indicating that farmers who interact more with extension agents are more efficient than those with lower frequency of interaction.

The findings of the study also revealed that FD is positively related to technical efficiency and this means that efficiency increases with increase in farm concentration. FA was however inversely proportional to efficiency indicating that soybean farmers who belong to farmer associations, farmer groups and cooperatives are less efficient than farmers who are independent.

5.3 Conclusions

This study set out to examine the influence of agglomeration externalities on the productivity and technical efficiency of soybean farms in the Upper East and Upper West Regions of Ghana. The results from the analysis of data collected from the field show that there is indeed the presence of such externalities.

Hypotheses tests on the models of estimation employed by the study show that the stochastic frontier and technical efficiency models used for the estimation of productivity and efficiency are the most appropriate for these measurements.

Internal returns to scale and agglomeration externalities are seen to be the main factors explaining the differences in output levels and productive performance. The input factors, seed, capital, labour and inoculant have positive elasticities and thus a positive impact on productivity, indicating that increases in the levels of use by farmers would lead to efficient production methods and significantly higher output levels. Inoculant/fertilizer is seen to have the biggest influence on the frontier. Diminishing returns to scale in the soybean sector also indicates less than proportionate increases in output with increases in inputs, which indicates ineffective resource combination among the farmers. Soybean farmers are therefore better of producing less.

The mean efficiency level in the soybean sector is low indicating that soybean farmers' efficiency is below optimum efficiency levels. This indicates high levels of inefficiency in the sector. Other studies carried out by researchers on soybean production in Northern Ghana produced similar outcomes for the technical efficiency levels of soybean farms. Farmers' efficiency levels fall too many points short of the frontier and this is largely due to inefficiency of input combinations and poor decision-making by farmers. The majority of the farmers were found to operate at efficiency

levels below 0.5. Output levels could increase by improving efficiency scores by 48 percent to achieve the 4.5 MT/hectare potential, with current input levels.

The results also established that some exogenous factors in the soybean sector have significant implications on technical efficiency. Efficiency decreases with increases in age of farmer. Older farmers were found out to be less technical efficient than younger farmers. Efficiency however increases with increases in the frequency of number of visits by extension agents to soybean indicating that farmers with more interactions with extension agents are more technically efficient. The results also show that female farmers are more technically efficient than male farmers in the soybean sector.

The results for the agglomeration indexes show that FA and FD have a significant positive influence on the production function. Increases in industry size through farm density (farm concentration or proximity of farms to each other) and by farmers belonging to farmer groups therefore increase the productivity of soybean farmers. The technical efficiency of soybean farmers increases with increases in farm density, however farmers who belong to farmer associations are less efficient than farmers who are not members of farmer agglomerates.

5.4 Recommendations

Agglomeration externalities have implications for technical efficiency and productivity in the soybean sector. There may however be high levels of negative externalities arising from farmer groups leading to less efficiency. These externalities need to be identified and minimized. Through the concerted effort of government, MoFA and NGOs, agglomerations of soybean farmers can be taught more efficient methods of farming to help increase their efficiency. Farmer groupings may give rise to farm densities and this should be encouraged. Some NGOs have already started grouping farmers and by virtue of this, farmers are locating their farms closer to each other. This

is laudable as it creates and fosters positive agglomeration externalities that arise from industry congestions. The government of Ghana and MoFA must put into motion policies that will strengthen and equip the FBOs, especially through education and capacity building. NGOs such as MEDA should also be empowered to better equip the soybean farmers.

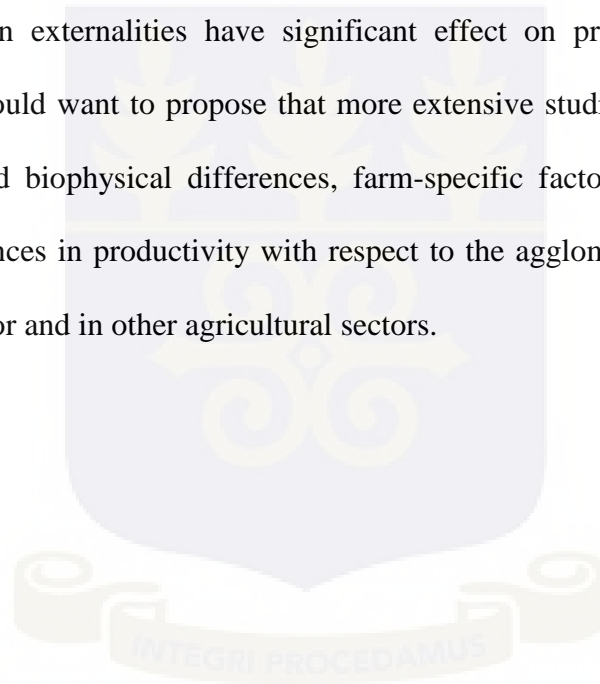
Seed, capital, labour and fertilizer have significant impact on productivity in the soybean sector. It is recommended that Ghana's Ministry of Food and Agriculture puts in efforts to facilitate easy access by farmers to seed and especially to inoculant (fertilizer) which has the highest impact on productivity. Through input-sharing, farmers in groups or in close proximity to each other can save on cost of acquiring inputs such as labour and farm equipment. Credit purchases should also be encouraged by MoFA especially for seed and inoculants. High yielding varieties of soybean should also be introduced to farmers to help them cut down on cost by increasing their yields.

Agriculture extension agents should have more regular interactions with soybean farmers, to teach them good farming practices and introduce new technologies to them so as to effect positive farming behaviour and better decision-making. Older farmers may be a lot more skeptical about new farming technology. Field trials, trial farms or demonstration farms should be set up, as is being done by MEDA through CARD, GROW, TUDRIDEP, to introduce such new technology to farmers to show them firsthand the positive results on yield. This will sway farmers towards the use of better technologies to improve their productivity and efficiency.

Government, the Ministry of Food and Agriculture and other stakeholders should organize workshops and seminars especially for older more experienced farmers to sensitize them about better production methods, good farming practices and more efficient input-use so as to make them more technically efficient. Also, MoFA and other stakeholders should complement the efforts of MEDA and other gender-inclined initiatives to further empower female soybean farmers by

improving their access to inputs and extension services so as to improve their efficiency and productivity. Male soybean farmers should however not be left out of such considerations since there is some level of disparity between their efficiency and that of female farmers. Regular workshops must be organized for soybean farmers to equip them and build their capacity to produce more and increase the efficiency with which they produce.

This study brings to the fore issues pertaining to productivity and technical efficiency in the soybean sector and the implications of agglomeration externalities on these parameters. The results show that agglomeration externalities have significant effect on productivity and technical efficiency. The study would want to propose that more extensive studies are carried out on the effects of biological and biophysical differences, farm-specific factors and regional industry infrastructure on differences in productivity with respect to the agglomeration externalities that exist in the soybean sector and in other agricultural sectors.



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APPENDICES

APPENDIX A: The Survey Instrument

**DEPARTMENT OF AGRICULTURAL ECONOMICS AND AGRIBUSINESS
UNIVERSITY OF GHANA, LEGON**

**AGGLOMERATION EXTERNALITIES, PRODUCTIVITY AND TECHNICAL
EFFICIENCY OF SOYBEAN FARMS IN THE UPPER EAST AND UPPER WEST
REGIONS OF GHANA**

QUESTIONNAIRE FOR THE SURVEY

This survey is being undertaken by the student as a requirement for his MPhil degree. The objective of the survey is to collect information to enable us assess the effect of agglomeration externalities on the productivity and efficiency of soybean farms in Ghana. All information gathered will be treated with confidentiality and will solely be for academic purposes. Your support and contribution will be appreciated.

Code [_ _ _]

Region:

District:

Town/Village/community:

Date of Interview:/...../ 2017

SECTION 1: SOCIO-ECONOMIC CHARACTERISTICS OF THE RESPONDENT

1. Name of respondent.....
2. Telephone number of respondent:
3. Gender: a. Male [] b. Female []
4. Age of respondent: years
5. Ethnicity:
6. Marital status: a. Single [] b. Married [] c. Divorced [] d. Separated [] e. Widowed []
f. Other [] specify,

7. Religion: a. Christian [] b. Muslim [] c. Traditional [] d. atheist [] e. Other [], specify.....

8. Level of Education: a. No schooling [] b. Primary school [] c. JHS [] d. SHS [] e. Tertiary [] f. Other [], specify,.....

9. Number of years spent to attain this level of education: years

10. What is the size of your household (including yourself)?person (s)

Number of adults (>18 years)		Number of children < 18	
Males	Females	Males	Females

11. Have you had access to extension services in the last farming season? a. Yes [] b. No []

12. If Yes, from which institution(s) did you receive the extension service? a. MoFA []

b. NGO [] c. Farmer Association/FBO [] d. Other(s) []

.....

13. If Yes, how many times did you receive such visits in the last farming season?

SECTION 2: AGGLOMERATION EXTERNALITIES

14. Do you belong to any Farmer Based Organization (FBO)? a. Yes [] b. No []

15. If yes to Q14, what is the name of the Farmer Association?

.....

16. How often do you meet as an association? a. Once a week [] b. Once a month [] c. Once every quarter [] d. Once a year [] e. Other [], specify

.....

17. If Yes to Q14, what benefits do you derive from being a member of the FBO? (*Multiple Response*) a. Inputs procurement [] b. Marketing [] c. Agro processing [] d. Production [] e. community services [] f. Internal credit schemes [] g. Welfare services [] h. Mutual labour support [] i. Other [] specify.....
18. What is the distance between you and the closest soybean farm? km
19. Which of the following would you say has improved and/or become readily available to you since you joined the FBO? (*Multiple Response*)
- a. Information on labour []
 - b. Knowledge on soybean farming techniques and practices []
 - c. Technology availability []
 - d. Industry infrastructure []
 - e. Advice []
 - f. Other(s)[], specify
.....
20. Which of the following negative externalities have arisen from your belonging to the FBO?
- a. Increase in incidence of diseases among crops []
 - b. Increase in incidence of pests []
 - c. Theft []
 - d. Water pollution []
 - e. Water unavailability []
 - f. Other(s) [], specify
.....
21. Which of the following negative externalities have arisen from your proximity to other soybean farms?

- a. Increase in incidence of diseases among crops []
- b. Increase in incidence of pests []
- c. Theft []
- d. Water pollution []
- e. Water unavailability []
- f. Other(s) [], specify

.....

SECTION 3: PRODUCTIVITY AND TECHNICAL EFFICIENCY

- 22. Number of years of experience in farming: years
- 23. For how long have you been cultivating soybean? years.
- 24. How many times do you cultivate/plant soybean in a year? a. Once [] b. Twice [] c. Other [], specify.....
- 25. Which other crops do you cultivate?

.....
.....

Farm Input:

- 26. What is the size of land used for soybean farming? Hectares [] / Acres []
- 27. What was the size of land for soybean farming before you joined the Farmer Association? Hectares [] / Acres []
- 28. What is the source of your land? a. Inheritance [] b. Purchase [] c. Rent [] d. Lease [] e. Other [], specify
- 29. If land is rented, what is the cost of rent per acre? GHS Monthly [] / Annually []

30. What was the cost incurred in acquiring the land? Fill the appropriate blank.

Purchase: GHS

Lease: GHS

Other: specify, GHS

31. Is soybean your main productive crop? a. Yes [] b. No []. If no, specify,

.....

32. What is your primary motivation for cultivating soybean? a. For income [] b. For consumption [] c. both []

33. How did you prepare your soybean farmland? a. Tractor ploughing [] b. Animal ploughing [] c. Manual (human-drawn) ploughing [] d. Traditional ploughing (Cutlasses, hoes, etc) [] e. Other [] specify

34. For each of the following, where applicable, indicate the size of land ploughed and the cost incurred:

Type of ploughing	Number of acres ploughed	Amount paid (GHS)

35. Please indicate the cropping system used on your soybean farm; a. Mono cropping [] b. Mixed cropping c. Other(s) [] specify

.....

36. Did you use certified soybean seeds? a. Yes [] b. No []

37. For your last planting season, where did you purchase or acquire your soybean seeds?

- a. Certified seeds dealer []
- b. Local seeds dealer []
- c. Own (stored) seeds []
- d. Farmer Association/FBO []
- e. Other(s) [] specify

.....

38. Please provide information on the following:

Seed/Seedling type	Quantity used/unit	Cost per unit (GHS)

39. Which of the following did you apply on your soybean farm in the last planting season?

- a. Inoculant/Fertilizer []
- b. Weedicide []
- c. Herbicide []
- d. Compost []

40. Fill the table where applicable for use of the following chemicals during the last planting season;

Chemicals	Quantity/unit (Kg/bag, litre)	Cost per quantity (GHS)
Fertilizer		
Pesticide		

Herbicide		
Compost		
Total (GHS)		

41. What is the main source of labour for your soybean farm? a. Private/hired labour []
 b. Family/friends [] c. Combination of the two [] d. Other [] specify

42. How much did you incur on labour this last season? GHS

43. Answer the following on labour-use on your soybean farm:

Activity	Number of people (labourers) used	Number of days used for activity	Number of hours used per day for the activity
Land preparation			
Sowing/Planting			
Harvesting			

44. Did you have access to credit for the last farming season? a. Yes [] b. No []

45. How did you finance your soybean farming activities?

- a. Credit []
- b. Personal Savings []
- c. Both []

46. If through credit, what form of credit was it?

- a. Credit in cash []
- b. Credit in kind [] specify

.....

c. Both specify for credit in kind

.....

47. If credit was in cash, what was the source of it?

- a. Bank
- b. Family/Friends
- c. Informal money lenders
- d. MoFA
- e. Farm Association/FBO
- f. Other(s) , specify

.....

48. What was the cost of credit?

49. What was the interest rate on credit? %

50. If credit was in cash, how much was it? GHS

51. If credit was in kind, what was the monetary value? GHS

52. Did you incur transportation cost during the last farming season? a. Yes b. No

53. If yes, how much did you incur on the following?

Transportation Type	Description	Cost (GHS)
To the farm		
Out of the farm		

54. Complete the following table on **fixed inputs** used for your soybean farming

Fixed Input	Description	Life span	Cost (GHS)
1. Cutlass 2. Hoe 3. Plough 4. Bucket 5. Jerry csn 6. Cup 7. Other(s):			

55. Complete the following table for inputs/items that were rented

Input	Cost of rent (GHS)
1.	
2.	
3.	
4.	
5.	

56. Did you incur any storage cost? a. Yes [] b. No []

57. If Yes, how much storage cost did you incur last farming season? GHS

Farm Output:

58. For farmers in FBOs, what was your annual farm output for soybean just before you joined the Farmer Association? bags kg

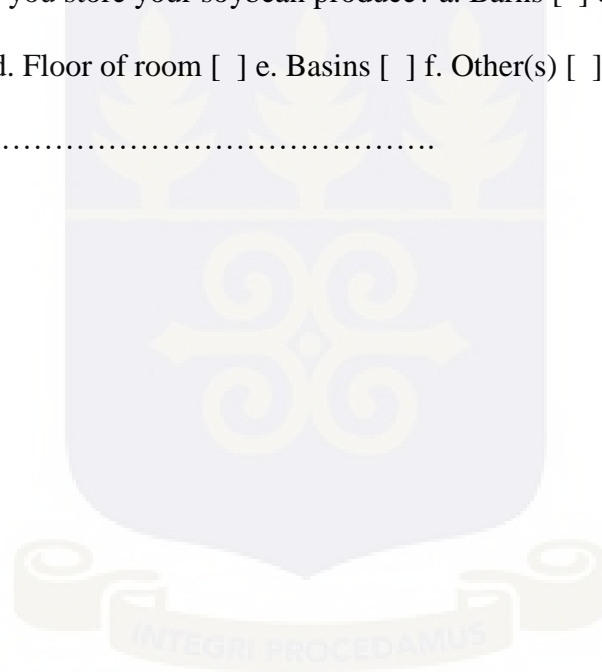
59. (a) What was your output for soybean in the last growing season? bags
..... Kg

What quantity of your output was consumed by you/your household? bags []
/kg []

(b) What quantity of your output was given away as gift? bags []/kg []

60. Did you set any per acre target for your farm? a. Yes [] b. No []
61. If yes to, how many bags did you target per acre? bags kg
62. How many bags did you actually harvest per acre? bags kg
63. Did you sell some of your soybean produce? a. Yes [] b. No []
64. If Yes, how many bags did you sell after harvest? bags kg
65. How much was each bag sold for? GHS/bag
66. Do you store your soybean produce? a. Yes [] b. No []
67. If Yes, where do you store your soybean produce? a. Barns [] b. Mud silos [] c.
Sacks/bags [] d. Floor of room [] e. Basins [] f. Other(s) [] specify

.....

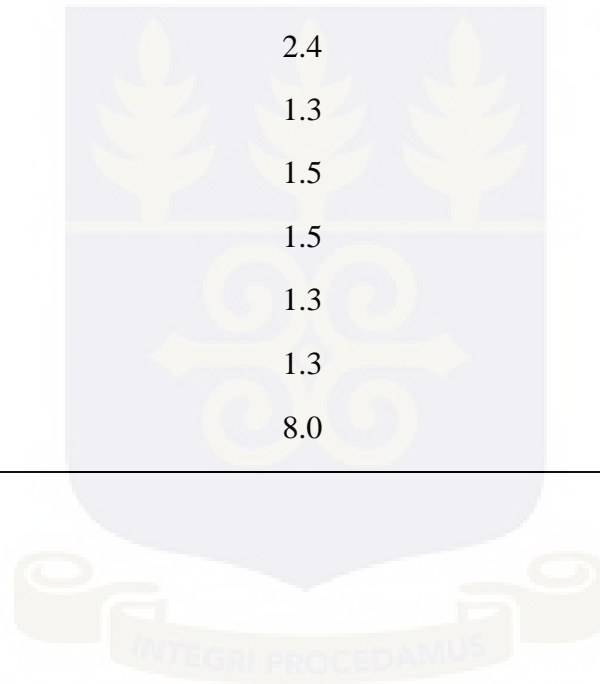


APPENDIX B: Average Crop Yields in Ghana

Table 5.1: Average crop yields in Ghana and their respective production frontier

Crop	Average Yield (MT/Ha)	Achievable Yield – Production Frontier (MT/Ha)
Cassava	13.8	48.7
Plantain	11.0	20.0
Yam	15.3	49.0
Cocoyam	6.7	8.0
Maize	1.7	6.0
Rice (Paddy)	2.4	6.5
Cowpea	1.3	2.6
Soybean	1.5	2.3
Groundnut	1.5	2.5
Millet	1.3	2.0
Sorghum	1.3	2.0
Sweet Potato	8.0	24.0

Source: MOFA (2010).



APPENDIX C: Estimates of the Stochastic Frontier Model

Table 5.1: Estimated stochastic frontier model

	Coefficient	Std. Error	robust - SE	t - value	p values
Constant	0.386389**	0.1749	0.1611	2.40	0.017
LnSEED	0.139101***	0.03638	0.03545	3.92	0.000
LnK	0.141429***	0.04739	0.04349	3.25	0.001
LnLAB	0.282621***	0.04595	0.04587	6.16	0.000
LnFERT	0.413061***	0.04690	0.05075	8.14	0.000
FD	0.0276757**	0.009645	0.01702	1.63	0.025
FA	1.022346*	0.3708	0.5952	1.72	0.086
.5*LnSEED^2	0.109832	0.04641	0.04354	2.52	0.012
.5*LnK^2	0.0604538	0.06324	0.06681	0.905	0.366
.5*LnLAB^2	-0.198560	0.1077	0.1079	-1.84	0.067
.5*LnFERT^2	-0.0497431	0.06231	0.05879	-0.846	0.398
LnSEED*LnK	-0.0484084	0.04023	0.03985	-1.21	0.225
LnSEED*LnLAB	-0.0113517	0.04796	0.04966	-0.229	0.819
LnSEED*LnFERT	0.00386704	0.03594	0.03474	0.111	0.911
LnK*LnLAB	0.0709928	0.06097	0.06187	1.15	0.252
LnK*LnFERT	0.0149701	0.05618	0.05777	0.259	0.796
LnLAB*LnFERT	0.0852065	0.05800	0.06437	1.32	0.186
$\ln\{\sigma_v\}$	-0.883637	0.05929	0.05847	-15.1	0.000
$\ln\{\sigma_u\}$	-1.09607	0.1575	0.1419	-7.72	0.000

** , * indicate significance at 5% and 10% respectively