

**PRODUCTION RISK AND TECHNICAL EFFICIENCY OF IRRIGATED
RICE FARMS IN THE GREATER ACCRA AND VOLTA REGIONS OF
GHANA**

BY

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

I, EDITH OGBOO ADINKU, author of this thesis titled “**PRODUCTION RISK AND TECHNICAL EFFICIENCY OF IRRIGATED RICE FARMS IN THE GREATER ACCRA AND VOLTA REGIONS OF GHANA**” do hereby declare that except for the references cited, which are duly acknowledged, this thesis is the product of my own research work in the Department of Agricultural Economics and Agribusiness, University of Ghana, from August 2011- July 2013. This thesis is not published or submitted either in part or in whole anywhere for the award of any degree.

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DEDICATION

I dedicate this thesis to my father Mr. Juluis T. Adinku for being such an inspiration and support to me in my academic pursuit. I also dedicate it to the loving memory of my mother Mrs. Sethina Osabutey-Adinku.



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ABSTRACT

This study aims to contribute to a better understanding of the possible causes of production volatility that has characterized rice production in the Greater Accra and Volta Regions of Ghana. The output gap that exists between actual yield and achievable yield presents an opportunity for output growth. Using cross sectional data, this study presents an empirical analysis of production risk and technical efficiency of 356 irrigated rice farms from the two regions. This study adopts the stochastic frontier model with flexible risk properties to estimate the level of technical efficiencies while accounting for production risk. Thus production variability is assessed from two sources, production risk and technical efficiency. A single stage maximization likelihood estimation using STATA 12 is considered to provide the estimates of the mean output, production risk and technical inefficiency models. This study also attempts to determine some socioeconomic characteristics and management practices which influence technical efficiency of rice production in the study area.

The findings demonstrate that the transcendental logarithmic (translog) production frontier is the best fit model for the mean output function. There is also the presence of technical inefficiency and production risk in the production process. The technical inefficiency effects are related to the exogenous variables. Input variables (scaled per hectare) such as fertilizer, seed, other cost and mechanization cost positively influence rice output whilst labour negatively influences rice output. The study also shows that farms in the study area exhibit increasing returns to scale. Fertilizer and mechanization cost reduce output risk whilst labour, seed and other cost increase output risk. The mean technical efficiency for the study area is 83.7 percent. There is a significant difference in mean technical efficiencies for irrigated rice farms in Greater Accra and Volta Regions. This study concludes that production risk and technical inefficiency prevents the rice farmers from realizing their frontier output. The best farm practices that improve upon the efficiency of the rice farmers in the study area include; employing the method of transplanting, the use of a harrow for tillage and the use of combined harvesters for harvesting. It was also realized that the extension services present in the area had very little influence on farmer efficiency.

This study recommends that inputs for rice production should be made readily available, affordable and accessible to farmers so that more may be employed to further increase output. The quantity of labour employed on the other hand should be reduced since an addition to labour would only be an addition to cost and not output. It further recommends the use of mechanized equipment and fertilizer as an effective means to mitigate the effect of production risk in the irrigated rice production process.

The extension and advisory services in the study area must be repackaged to enhance their effectiveness and impact in the study area. Farmers should also be encouraged to

use best agronomic practices through the extension and advisory services to help improve technical efficiency.

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ABBREVIATIONS AND ACRONYMS

AGRA	Alliance for Green Revolution in Africa
ARC	Africa Rice Center
CARD	Coalition for Africa Rice Development
FASDEP11	Food and Agricultural Sector Development Policy
GIDA	Ghana Irrigation Development Authority
JICA	Japan International Cooperation Agency
MDG	Millennium Development Goal
METASIP	Medium Term Agricultural Sector Investment Plan
MiDA	Millennium Development Authority
MOFA	Ministry of Food and Agriculture
NEPAD	New partnership for Africa Development
NRDS	National Rice Development Strategy
SF	Stochastic Frontier
SSA	Sub-Saharan Africa
WARDA	West Africa Rice Development Association

CHAPTER ONE

INTRODUCTION

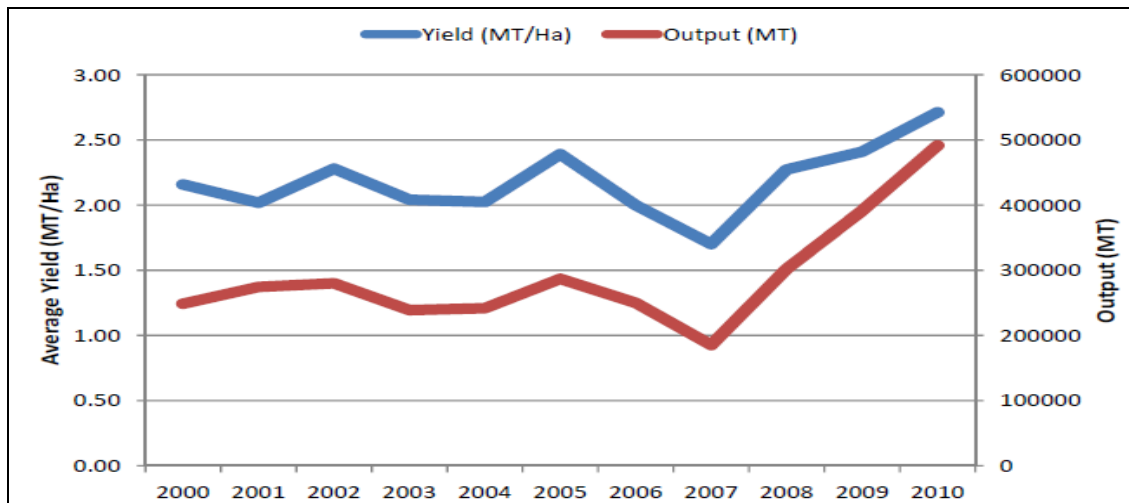
1.1 Background

Rice (*Oryza sativa*) is an important food staple for the African continent. Africa has become a major participant in international rice markets, with rice accounting for 32 percent of all global imports into the continent (WARDA, 2007). Africa's emergence as a big rice importer is due to the fact that in the last decade, rice has become the most rapidly growing food source across the continent (WARDA, 2007). With an increasing population growth rate (4 percent per annum), rising incomes and a shift in consumer preference in favor of rice, especially in urban areas (Balasubramanian et al., 2007), the relative growth in demand for rice is faster throughout the sub-regions of sub-Saharan Africa (SSA) than anywhere in the world (WARDA, 2011). In 2009 the continent imported one third of what was on the world market costing an estimated US\$ 5 billion (WARDA, 2011). However, this attempt to cater for the deficit in supply of rice is expensive and unsustainable and may eventually lead to severe food insecurity and civil instability especially in African countries that rely heavily on rice as a main source of staple food.

In Ghana, rice cultivation can be traced down to the 17th and 18th centuries. During that time, rice was already one of the major commercial food crops (Mobil and Okran, 1985). Most of the people involved in rice cultivation at that time were small scale subsistence farmers, who cultivated rice under the bush/fallow system and shifting cultivation systems.

In this 21st Century, rice has become the second most important staple food after maize in Ghana and its consumption keeps increasing as a result of population growth, urbanization and a change in consumer habits (NRDS, 2009). Rice has become an important staple for both rural and urban dwellers and is gradually taking over from traditional crops such as roots and cereal crops (Quaye et al., 2000). Urban markets in Ghana represent 76 percent of total rice consumption. (MiDA, 2010).

In Ghana, rice is one of the five selected food security commodities that have been articulated in the country's Medium Term Agriculture Sector Investment Plan (METASIP, 2009). The National rice development strategy was subsequently initiated in 2009 with the idea of doubling local rice production from 14 to 28 million tons by 2018. Figure 1.1 shows the trend in paddy rice production and yield from the year 2000 to 2010. From the diagram, it can be seen that both yield and rice production were essentially flat between 2000 and 2005. From the year 2005 to 2007 there was the observance of a decline in both yield and production. From 2007 however, both yield and production have been increasing. It is reported that domestic paddy rice production in Ghana increased by 165 percent between 2007 and 2010 while yield increased by 59 percent in that same period (Boadu, 2011). Results that may be attributable to the focused attention that both the Government of Ghana and its development partners have brought to rice production in the last few years.

Figure 1.1: Paddy rice production and yield trend for Ghana (2000-2010)

Source: FAO (<http://www.faostat.org>) and MOFA as cited in (Boadu, 2011)

Rice in Ghana is cultivated as a food crop and a cash crop under three different ecologies namely: Valley-bottom rice, upland rice and irrigated ecology/schemes. Valley-bottom rice constitutes 78 percent of total production, Upland rice, 6 percent and Irrigated schemes, 16 percent (MAPS, 2003). The Valley-bottom and Upland rice are considered as traditional methods of rice production and these make use of cultivars of African rice, *Oryza glaberrima*. Although individual production is on small scale it is extremely widespread.

For the Valley-bottom rice system, the rice is planted in small quantities in valley bottoms mostly in the region north of the forest area in Ghana. A typical area for the cultivation of valley-bottom rice is the Fumbisi valley which is found at the southwestern part of Sandema i.e. west of the White Volta. Rain fed cultivation of (largely) Asian rice

is predominant in this region. The Tolon Kumbungu District which is 60 km west of Tamale is also a lowland rice growing area.

Upland rice is grown mainly in the mountainous areas of the Volta Region, between the Volta Lake and the Togolese border. The rice area stretches between Ho and Nkwanta. Rice is regarded in this region as a central staple and the agricultural year revolves around its cultivation. Varieties grown here are mostly the 'traditional rice' *Oryza glaberrima* although some early varieties of *Oryza Sativa* are also present.

The Irrigated schemes usually comprise of large scale rice projects that depend on pumps, dams and other elaborate water channeling. The Ghana irrigation development authority is in charge of all Government irrigation schemes. It is estimated that the contribution of irrigated agriculture to the total national rice production needs to be about 24 percent in order to satisfy national demand (Owusu and Nyantakyi, 2003). These schemes often focus on the cultivation of high- input rice varieties.

Ghana's agriculture sector has the sole role of providing food security, supplying raw materials to industry, the creation of employment opportunities and the earning of foreign exchange (Asare-Osei, 2010). Its dominant role in the economy of Ghana makes this sector a target for national development programmes and strategies. Since the early 1970s, several interventions have sought to revive and develop the rice industry. National and agricultural development plans and strategies, such as the Food and Agriculture Sector Development plan (FASDEP II 2009-date) and the Medium Term Agriculture

Sector Investment Plan (METASIP 2011-2015) has since featured rice as one of the targeted food security crops. It is the broad strategy of the FASDEP II to attain food security through the promotion and development of five staple crops (i.e., maize, rice, yam, cassava, and cowpea) by focusing at the national and agro-ecological levels. The strategic objectives for the agricultural policy (FASDEP II) are the programme areas in the METASIP. These are ; food security and emergency preparedness, improved growth in incomes and reduced income variability, increased competitiveness and enhanced integration into domestic and international markets, sustainable management of land and environment, science and technology applied in food and agriculture development and improved institutional coordination. The METASIP targets to increase the rice self-sufficiency ratio from 22 percent in 2009 to 75 percent by 2015.

Ghana has also aligned itself with the Coalition for African Rice Development (CARD) initiative. CARD was formed with the objective of doubling rice production in Sub-Saharan Africa from 14 to 28 million tonnes in 10 years (Asare-Osei, 2010).

This is in an attempt to meet one of the millennium development goals (MDGs), which is to eradicate extreme poverty and hunger. Each CARD member country was made to design a National Rice development Strategy. Ghana's national rice development strategy has the main goal of contributing to national food security, increased income and reduced poverty towards the attainment of self sufficiency from sustainable rice production (NRDS, 2009). It was developed by the Ministry of food and Agriculture and it focuses on seven thematic areas, namely: Seed production system, fertilizer marketing and distribution, post-harvest handling and marketing, irrigation and water control

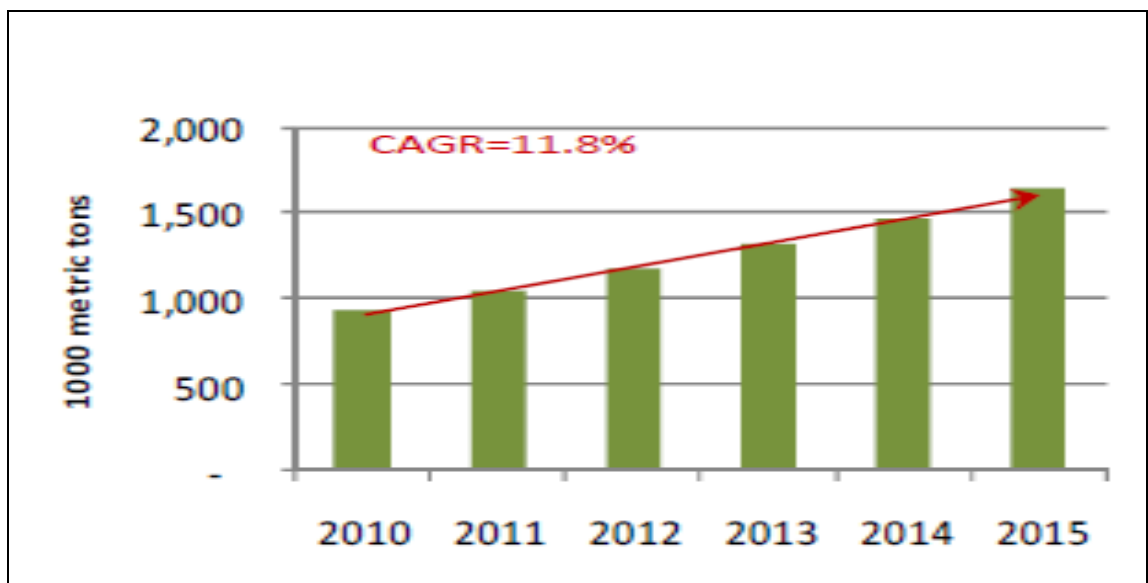
investment, equipment access and maintenance, research and technology dissemination, community mobilization, farmer-based organizations and microcredit management.

1.2 Research Problem

The importance of rice to the Ghanaian economy cannot be underestimated. From a steady level of 7-8 kilograms per year through 1990, per capita rice consumption increased to 11.5 kilograms per year on average during the 1990s and climbed considerably to 27 kilograms per year for the period from 2001-2005 (MiDA, 2010). The Ministry of food and agriculture projects that there will be a persistent increase in the demand for rice in Ghana.

The Ministry has projected that (Figure 1.2), the demand for rice in Ghana will increase at a compound annual rate of 11.8 percent from 939,920 metric tons to 1,644,221 metric tons between 2010 and 2015 (MiDA 2010).

Figure 1.2: Projected Domestic demand for rice



Source: MiDA (2010)

Despite the observed growth in rice production since 2007 (Figure 1.1), the demand for rice far out ways its supply and as such Ghana has been importing significantly larger quantities of rice to address quantity differences between local production and demand.

Rice imports from Thailand, Vietnam, the U.S. India and Pakistan have grown considerably to fulfill Ghana's increasing demand because domestic rice suppliers have not been able to keep up (Asare-Osei, 2010).

Average rice imports were 348,182 metric tons between 2003 and 2008, representing 69 percent of total national rice consumption (MiDA, 2010). The rice import bill is currently estimated at US\$500 million annually and has become a source of concern to the Ghanaian government. The development of Ghana's rice sector is a potential engine for economic growth which will also contribute to eliminating extreme poverty and food insecurity in Ghana. Development of the rice sector and related sectors will have considerable impact on the competitiveness of the Ghanaian economy and reduce the need to divert valuable foreign currency exchange to imports. It will also create employment along the value chain and lead to improved nutritional and health status of the rural agricultural poor (WARDA, 2011).

It is estimated that about 70 percent of the increase in rice production in Africa is mainly due to land expansion and only 30 percent attributed to an increase in productivity (Fagade, 2000; Falusi, 1997; WARDA, 2007). The solution to bridging the gap between demand and supply of rice lies with increasing domestic rice production. In developing countries like Ghana, the adoption of new technologies may be costly to undertake.

Instead, an assessment of the already existing technologies in terms of their extent of utilization is essentially required.

The realization of output is uncertain and the ability of farmers to obtain maximum yields given a set of input factors is often influenced by their input decisions as well as environmental factors. Certain input factors may contribute positively to the realization of output while others may not. Environmental factors such as the incidence of pests and diseases, drought and floods ultimately affect the ability of a farmer to obtain high yields. Every farmer's goal is to employ input factors in such a way as to obtain the maximum achievable yield. Large variations between observed yields and maximum achievable yields are therefore undesirable. Farmers' input choices tend to affect the extent of output variability observed. The employment of certain input factors in the production process may result in the observance of high fluctuations in yield and others may not. The nature of the input factors with regards to how they affect output variability (risk) is therefore necessary for input allocation decisions. The variability of output with respect to input use is the risk associated with the production process.

Given the fact that risk considerations may be a factor when choosing between production plans as it might influence observed production output, it is necessary to take it into account when assessing the performance of the rice production industry. In assessing the rice production industry, certain socioeconomic and managerial factors that may boost production should also be identified. The estimation of technical efficiency using the conventional stochastic model proposed by Aigner et al. (1977) fails to

adequately address this important aspect of production which is production risk. Not accounting for production risk with respect to input use, results in biased estimates of technical efficiency. These biased estimates may be misleading to policy makers. This study therefore employs a stochastic frontier model with a flexible risk component.

A few studies have been conducted in Ghana in an attempt to estimate the technical efficiency of rice farmers especially in the Northern Region. These include the study done by Al-hassan (2008) study on technical efficiency of rice farmers in Northern Ghana and the study done by Donkoh et al. (2013) on the technical efficiency of rice production at the Tono Irrigation Scheme in Northern Ghana. These studies employed the conventional estimation of stochastic frontier analysis proposed by Aigner et al. (1977) and as such failed to account for production risk in the production process. This results in biased estimates of technical efficiency (Villano and Fleming 2006). No comprehensive study has been undertaken in Ghana to analyze technical efficiency of rice farms whilst accounting for the effect of risk. This study therefore estimates technical efficiency of rice farms whilst accounting for risk in order to obtain unbiased estimates of technical efficiency. From the afore -mentioned the major questions that arise are:

1. What are the contributions of the various inputs to output?
2. What is the production risk with respect to input use?
3. What are the technical efficiency levels of rice production?
4. What are the factors that influence the technical efficiency of rice production?

1.3 Objectives

The priority of this study is therefore to analyze the production risk and technical efficiency of rice production in the Greater Accra and Volta Regions of Ghana.

Specifically, the study seeks to;

1. Estimate rice productivity with respect to the various inputs.
2. Estimate the production risk with respect to the input factors.
3. Estimate the technical efficiency levels of rice farms.
4. Identify the factors that affect the technical efficiency of rice farms.

1.4 Justification of the Study

Estimates of the productivities of the input factors to rice output will provide insight about the relationship of the various input factors to output. The extent to which output will change if the input factors are changed. The estimated scale elasticity of production also gives an indication of the change in output if all the factor inputs are varied by the same proportion in the long run. These estimates help to inform policy on the right input mix which will result in increased output.

The findings from the production risk component will give insight into how the individual inputs affects variations in output. Some input factors may tend to increase output variance while others may not. This information is necessary for input allocation decisions.

The technical efficiency levels will also give an indication of the extent of utilization of the present technology employed in the production process, and the potential for improvement. There is uncertainty associated with input use in every production process which should be accounted for when accounting for technical efficiency. Relevant factors that can improve technical efficiency in the rice production process in the Volta and Greater Accra Regions will be identified. This information will provide useful information for all stakeholders that are involved in the design and implementation of programs and policies aimed at improving rice production in Ghana. An improvement in technical efficiency of production will evidently result in increased output which will also ultimately go a long way to affect the income of the farmer and also improve their standard of living. The outcome of this study will also contribute to literature on the improvement of technical efficiency of the rice production industry and also the mitigation of risk in the rice production process in Ghana.

1.5 Organization of the thesis

This thesis is organized into five chapters. Following the chapter one, chapter two presents the literature review. This consists of the various efficiency measurements; the deterministic and stochastic frontier approaches, production risk, the incorporation of production risk in the stochastic frontier model as well as the empirical applications of the stochastic frontier analysis. Chapter three outlines the methodology employed for the study. This includes information about the method of analysis i.e. the conceptual framework, theoretical framework, empirical analysis for estimating technical efficiency and production risk and the hypothesis test. It also outlines the data and sampling

technique employed and information about the study area. Chapter four presents the results and discussion of the study with respect to each specific objective. It presents summary statistics of the output and input variables, a description of some socioeconomic characteristics of the respondents. It also presents the results of the various hypotheses that were tested, the estimates of the marginal output risk and the inefficiency model estimates. Finally the summary, conclusions and policy recommendations of the study are presented in chapter five.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the various methodologies needed for estimating technical efficiency and production risk under the stochastic frontier model, whilst the incorporation of exogenous influences into the frontier model are highlighted.

2.2 Efficiency Measurements

The concept of efficiency is founded on the economic theory of production. Efficiency refers to the extent of utilization of resources. It is the relationship between what an organization (producer, production unit, or any decision-making unit) produces and what it could feasibly produce, under the assumption of full utilization of the resources available (Garcia del Hoyo et al., 2004). In reference to the conceptual framework stated by Kumbhakar and Lovell (2000), efficiency represents the degree of success which producers achieve in allocating the available inputs and the outputs they produce, in order to achieve their goals which is to attain a high degree of efficiency in cost, revenue or profit. The production frontier is therefore the maximum output attainable by a given set of inputs and existing production technologies. The production frontier defines technical efficiency in terms of a minimum set of inputs in order to produce a given output. If a producer produces less than what he could feasibly produce then he is lying below the frontier. The distance by which a producer lies below the production frontier is a measure

of his inefficiency (Garcia del Hoyo et al., 2004). Farrell (1957) was the first to empirically measure productive efficiency in terms of deviations from an ideal frontier. Farrell (1957) decomposed economic efficiency into technical efficiency and allocative efficiency. He defined Technical efficiency (TE) as a measure of the ability of a producer to obtain the maximum output from given inputs and subsequently defined allocative efficiency (AE) as the ability of a producer to use inputs in optimal proportions. Economic efficiency is a situation in which technical and allocative efficiency is combined. One of the main issues is whether inefficiency occurs randomly, or whether some economic agents (producers, firms or economies) have predictably higher levels of inefficiency than others. First and foremost efficiency estimation provides an indication of the percentage by which potential output could be increased, or potential cost could be decreased, in relation to the corresponding production frontier.

The main methods of efficiency estimation can be classified into two core groups namely: Non-parametric and parametric approaches.

- a. The non-parametric frontier technique which has conventionally been assimilated into the Data Envelopment Analysis (DEA) was developed by Farrell (1957) and Charnes et al. (1978). It uses mathematical programming methods in constructing the efficient frontier. It also uses the calculus of efficiency scores relative to those constructed frontiers.
- b. The parametric approach was developed by Aigner et al. (1977) and Meeusen and Broeck (1977) in the context of the deterministic frontier and stochastic frontier approaches.

The non-parametric frontier technique uses linear programming thereby making it less liable to specification error (Tewodros, 2001) whilst the parametric frontier approach on the other hand uses econometric or statistical techniques and confounds misspecification of functional form effects with inefficiency. Most often the parametric approach is preferred by researchers because the non-parametric approach does not impose a functional form on the data but assumes a constant returns to scale. This makes relaxing the assumption of constant returns to scale cumbersome. Another disadvantage of the non-parametric approach is that the frontier is supported by a subset of output and input observations which is susceptible to extreme observations and measurement error (Ajibefun, 2008).

The advantage that the parametric has over the non-parametric approach is its ability to represent the technology frontier in a simple mathematical form and to use non-constant returns to scale of the frontier production function. However, applying the parametric approach under mathematical programming imposes a limitation on the number of observations that should be technically efficient (Tewodros, 2011). A typical example is seen when using a Cobb- Douglas case, for example, when the linear programming algorithm is used, there is generally as many technically efficient observations as there are parameters to be estimated. Another problem of the parametric approach under mathematical programming is that the estimates are sensitive to outliers and measurement errors since the estimates are supported from a subset of data. The disadvantages of the parametric technique under linear programming are overcome by using

econometric techniques of estimation in the deterministic and stochastic frontier approaches.

2.2.1 Deterministic Frontier Approach

The first researchers to estimate a deterministic frontier production using a Cobb-Douglas production function are Aigner and Chu, 1968 .They argued that within any industry, producers may differ from each other in terms of their production processes because of certain technical parameters in the industry, differences in scale of operation or due to organizational structures. The deterministic frontier model is defined in a cross section perspective as:

$$Y_i = f(X_i; \beta) \exp(u_i) \quad i= 1, 2, \dots, N \quad (2.1)$$

Where Y_i represents the possible production level for the i -th sample farm bounded above by a deterministic component $f(X_i; \beta)$. The $f(X_i; \beta)$ is a suitable function of the vector, X of inputs for the i -th farm and a vector, β of unknown parameters; u_i is a non-negative random variable representing the inefficiency in the production process. The technical efficiency of individual firms is defined in the case of deterministic frontier as the ratio of observed output Y_i to the corresponding estimated frontier output or the maximum feasible output $Y_i^* = f(X_i; \beta)$ and so the technical efficiency for the deterministic approach is denoted by;

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{f(x_i; \beta) \exp(-u_i)}{f(x_i; \beta)} = \exp(-u_i) \quad (2.2)$$

The technical efficiency measure takes a value between zero and one, $TE = 1$ shows that the producer is fully productive efficient and correspondingly, the observed output reaches its maximum obtainable value. $TE < 1$ provides a measure of the shortfall of the observed output from maximum feasible output. Although the deterministic frontier technique is subjected to statistical analysis it regards all deviations in output as technical inefficiency effects regardless of the fact that the deviations in output might be contributed by random errors including weather effects and errors of measurement which are beyond the control of the producer. The limitation in the deterministic frontier modeling approach is addressed by the stochastic frontier model. It was an attempt not only to account for technical inefficiency, but also for measurement errors or statistical noise.

2.2.2 Stochastic Frontiers

The stochastic frontier approach (SFA) was independently proposed by Aigner et al. (1977) and Meeusen and Broeck (1977). In order to incorporate this feature, there was a need to introduce another random variable representing any statistical noise or measurement errors. The stochastic model therefore includes a composite error term that sums a two-sided error term, hence allowing for the measurement of all effects outside the producers control, and a one-sided, non-negative error term, measuring technical inefficiency. The resulting frontier is presented in terms of a general production function, known as a stochastic production frontier.

For a cross sectional model, it is specified as;

$$Y_i = f(X_i; \beta) \exp(\varepsilon_i) \quad i= 1, 2, \dots, N \quad (2.3)$$

Where Y_i (realized output of farm i) is bounded above by the stochastic component $f(X_i; \beta) \exp(v_i)$. The $f(X_i; \beta)$ is the production frontier, the X_i 's represent the vector of inputs, β is a vector of the unknown technology parameters. The composed error term is $\varepsilon_i = v_i - u_i$, where v_i captures the effect of pure noise in the data attributed to measurement error, extreme weather conditions etc. and the one-sided inefficiency effects are denoted as u_i . Technical efficiency of an individual firm from the stochastic frontier perspective is defined in terms of the ratio of the observed output to the corresponding stochastic frontier output, given the levels of inputs used by that firm. Thus, the technical efficiency of a firm in the context of the stochastic frontier production function is given by;

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{f(x_i; \beta) \exp(v_i - u_i)}{f(x_i; \beta) \exp(v_i)} = \exp(-u_i) \quad (2.4)$$

In the deterministic approach, all deviations in output are regarded as technical inefficiency effects (i.e. $\varepsilon_i = u_i$) regardless of the fact that the deviations in output might be contributed by random errors including weather effects and errors of measurement which are beyond the control of the producer. The stochastic frontier model therefore separates the pure noise component from the technical inefficiency effects. The

estimation of technical efficiency using the conventional stochastic model proposed by Aigner et al. (1977) fails to adequately address an important aspect of production which is production risk. Not accounting for production risk results in biased estimates of technical efficiency.

2.2.3 Production Risk

Output risk is an inherent part of the production process of most primary industries e.g. Agriculture, mining and oil extraction (Asche and Tveteras, 1999). Even more so in developing countries where subsistence agriculture predominates, production risk is an issue of great concern. Any production related activity or event that is uncertain is characterized as production risk. Agricultural production implies an expected outcome or yield. Variability in outcomes from those expected yield creates risks to the producer's ability to achieve financial goals. Reducing variability in expected yields has been a major focus of farm managers.

The conventional stochastic frontier model in the equation 2.3 above proposes the same effect of an input on mean output and variance output. Implying that if an input influences output positively, that input is expected to influence output variance positively and vice versa (Coelli et al., 2005). However the Just and pope (1978) production function proposes a separate effect of the inputs on the mean output and the variance of output or output risk. The factors of production can positively contribute to output but relate negatively to output variance. For example, pesticides, irrigation and disease-resistant seed varieties can reduce output variance and simultaneously, contribute

positively to output in a given production process. These inputs are categorized as risk reducing inputs. On the other hand, inputs that influence output variance positively are termed as risk increasing inputs. Just and Pope concluded that the effect of an input on output variance should not be tied prior to output variance but the risk effect of an input depend on empirical studies. (Just and Pope, 1978).

The production environment is uncertain and producers input use decisions, as well as environmental factors ultimately affects output. The variability in output as a result of certain input decisions is the risk associated with input use. In countries where subsistence agriculture predominates, production risk is an issue of great concern. One very important characteristic of a risky production process is the observance of random production shocks after certain inputs decisions have been made. With respect to relative input uses, a source of deviation from competitive levels is the inputs marginal contribution to the level of output risk (Asche and Tveteras, 1999). Some inputs may reduce the level of output risk, while others may increase risk (Asche and Tveteras, 1999). Production uncertainty is therefore one of the most important ingredients in the formulation of government policy in the inputs decision making of producers (Just and Pope 1978).

Agricultural risk can be categorized into two main types namely, production risk which is characterized by high variability of production outcomes and price risk resulting from volatility of the prices of agricultural output and inputs. The effect of risk and uncertainty is more significant in developing countries due to market imperfections, asymmetric information and poor communication networks (Fufa and Hassan, 2003 ;Wanda, 2009).

The stochastic nature of agricultural production is in most cases a major source of risk, because, variability in yield is not only explained by factors outside the control of the farmer such as input and output prices, but also by controllable factors such as varying the levels of inputs. (Antle, 1983). A risk averse farmer thus uses more of a risk reducing factor than a risk neutral farmer (Pope and Kramer, 1979). Some inputs may reduce the level of output risk (e.g. pesticides) while others may increase risk (Asche and Tveteras, 1999). The first attempt to separate the effect of the inputs on the mean output and the variance of output or output risk was by Just and pope (1978). The Just and Pope (1978) production function is represented as shown below:

$$Y_i = f(X_i; \alpha) + \exp g(X_i; \beta)v_i \quad (2.5)$$

$g(X; \beta)v_i$ represents the idiosyncratic component of production risk as a result of farm specific factors. Given that the mean output function is $E(Y_i) = f(x_i)$ and the variance of output is

$V = g^2(x_i)$, the marginal production risk, which measures the effect of input on the production risk is given by:

$$\frac{\partial \text{var}(Y_i)}{\partial X_i} = 2g(X_i; \beta)g_i(X_i; \beta) \quad (2.6)$$

The marginal risk can be positive as well as negative, depending on the signs of

$g(X;\beta)$, and $g_i(X;\beta)$. Where the latter is the partial derivative of the g with respect to input i . A positive marginal risk means the input has an increasing effect on the output risk and a negative value means that the input has a decreasing effect on the output risk, (Just and Pope, 1978). Therefore estimating efficiency to account for production risk depends on the input levels.

A lot of work has been done in attempt to provide empirical evidence on how risk influences the nature of decisions in agricultural production.

These attempts can be categorized into two groups of studies. The first group aimed at estimating producer's attitude towards risk that influences their input allocation and output supply decisions. These studies have employed either the experimental or econometric approaches to elicit risk attitudes of individual producers. The experimental approach is based on hypothetical questionnaires regarding risky alternatives or risky games with or without real payments (Wik et al., 2004). Among the studies that have employed this approach include; Binswanger (1980, 1981) that used risky games with real payments to measure Peasant's risk preferences in an experiment in India. The econometric approach is based on individuals' actual behaviour assuming expected utility maximization. Studies that have used this approach to elicit producer's risk attitudes include; Antle (1983), Love and Bucolla (1991), Pope and Just (1991). However, the econometric approach has been criticized for confounding risk behaviour with other factors such as resource constraints faced by individual decision makers (Wik et al., 2004). This is particularly important in developing countries where market imperfections are prominent and production and consumption decisions are non-separable (Sadoulet and de Janvry, 1995).

The second group of studies has attempted to investigate the influence of risk on agricultural production by directly incorporating a measure of risk in the traditional production functions. Such studies include work by Just and Pope (1979) that focused on production risk, measuring it by variance of output. They also suggested the use of the production function specifications satisfying some desirable properties. The main focus in their specification is to allow inputs to be either risk increasing or risk decreasing. The Just-Pope framework, however, does not take into account producer's attitude towards risk (Kumbhakar, 2002). Love and Buccola (1991) extended the Just-Pope function to consider producer's risk preferences in a joint analysis of input allocation and output supply decisions.

Wan and Battese (1992) proposed an alternative stochastic frontier production function which permits the estimation of technical efficiency to account for production risk.

This study belongs to the second group of studies where the influence of production risk is investigated by directly incorporating a measure of risk in the traditional production function.

2.2.4 Incorporation of Production Risk in the Stochastic Frontier Model

In estimating technical efficiency, the model adopted must account for technical inefficiency, pure random noise effect and production risk. Works that have been done in this area of research have employed one of the three variations outlined below. The various models differ according to how the inefficiency effect has been incorporated into the model. The first possibility adds the inefficiency effect to the variance function

together with the random noise component representing the effects of uncertainty as shown below (Battese et al., 1997).

$$Y_i = f(x_i; \alpha) + g_i(x_i; \beta)(v_i - u_i) \quad (2.7)$$

The second possibility is the multiplicative form, where the inefficiency effect is added to the mean output function (Kumbhakar, 2002).

$$Y_i = f(x_i; \alpha)(1 - u_i) + g(x_i; \beta)v_i \quad (2.8)$$

In this case an additional assumption; $\exp\{-u_i\} = 1 - u_i$ has to be introduced. The third is a more flexible form suggested by Kumbhakar (2002), where an additional function $q(x)$ for explaining technical inefficiency is introduced:

$$Y_i = f(x_i; \alpha) + g_i(x_i; \beta)v_i - q(x_i; \gamma)u_i \quad (2.9)$$

Where $f(x_i; \alpha)$ is the mean production function and $g_i(x_i; \beta)$ is the production risk function.

α is the vector of mean production parameters and β is a vector of output risk parameters. The v_i is the stochastic term and the u is the non-negative inefficiency variable. $q(x_i; \gamma)$ explains technical inefficiency and the x_i 's are the input variables. According to equation 2.9 above which is also in line with the formula proposed by Battese and Coelli (1998),

technical efficiency is measured by the ratio of the observed output given its value of inputs and an inefficiency effect to the frontier output is given by;

$$TE_i = \frac{E(Y_i / X_i, U_i)}{E(Y_i / U_i = 0)} = \frac{f(x_i; \alpha) - g(x_i; \beta)u_i}{f(x_i; \alpha)} = 1 - \frac{ug(x_i; \beta)}{f(x_i; \alpha)} \quad (2.10)$$

The technical inefficiency, TI is represented as;

$$TI_i = \frac{ug(x_i; \beta)}{f(x_i; \alpha)} \quad (2.11)$$

Technical efficiency therefore becomes;

$$TE_i = 1 - TI_i \quad (2.12)$$

From equation 2.11 above, it can be seen that technical inefficiency (TI) depends positively upon the production risk function and negatively on the mean output if there were no inefficiencies. This means that technical efficiency is also dependent upon production risk. It is therefore important to incorporate production risk into the stochastic frontier model. The conventional stochastic frontier model on the other hand proposes that technical efficiency is dependent on the one sided random error only; $TE_i = \exp(-u_i)$. In the multiplicative model of the conventional stochastic frontier model, technical efficiency is given by;

$$TE_i = 1 - u \frac{f(x_i)}{f(x_i)} \quad (2.13)$$

$$TI_i = u \frac{f(x_i)}{f(x_i)} = u_i \quad (2.14)$$

Technical inefficiency however does not depend upon only the input levels as stated in equation 13 above. For this study production risk is accounted for in its estimation of technical efficiency as illustrated in equation 2.10. This formula adjusts the technical efficiency scores depending on the effects of the inputs on production risk. This allow for unbiased estimates of technical efficiency to be obtained.

2.2.5 Stochastic frontier model estimation

The estimation of the stochastic frontier for statistical analysis is underpinned by certain distributional assumptions of the v and the u . Following Battese and Coelli (1995), the v is assumed to be independent of the u , and both errors are uncorrelated with the explanatory variables. Consistent with the conventional classical assumption, the v and u are specified as shown below;

$$E(v) = 0 \quad (\text{Zero mean})$$

$$E(v_i^2) = \sigma_v^2 \quad (\text{Homoscedastic})$$

$$E(v_i v_j) = 0 \text{ for all } i=j \quad (\text{Uncorrelated})$$

$$E(u_i^2) = \text{constant} \quad (\text{Homoscedastic})$$

$$E(u_i u_j) = 0 \text{ for all } i \neq j \quad (\text{Uncorrelated})$$

Based on the assumptions of the v_i 's and the non-negative u_i 's the Ordinary least square Estimator can be used to estimate the model but the coefficient of the intercept term is biased downwards. This may be corrected by applying the corrected least square estimators under certain distributional assumptions. It is however more appropriate to apply the maximum likelihood method of estimation. Assuming that the v_i 's are independently and identically distributed with zero mean and constant variance and the u_i 's are distributed as any of the following assumptions below independent of the pure noise:

$$U_i \approx iiN^+(0, \sigma_u^2) \quad (\text{Half Normal})$$

$$U_i \approx iiN^+(u, \sigma_u^2) \quad (\text{Truncated Normal})$$

$$U_i \approx iiG(\lambda, 0) \quad (\text{Exponential})$$

$$U_i \approx iiG(\lambda, m) \quad (\text{Gamma})$$

The choice of distributional specification with respect to the U_i is sometimes a matter of computational convenience. Frontier 4.1 has an inbuilt statistical package that is used to estimate half-normal and truncated-normal models. LIMDEP can be used to estimate half normal, truncated normal and exponential models. Theoretical considerations may also affect the choice of distributional specification. The half-normal and exponential distribution assumes that most inefficiency effects are close to zero with associated technical efficiency approaching one. The truncated normal and gamma models allow for

a wider range of distributional shapes but, there is a cost of computational complexity owing to the fact that there are more parameters to estimate and the probability distributional functions for the u_i 's and v_i 's may have similar shapes which can make it difficult to distinguish inefficiency effects random noise (Coelli et al., 2005). Based on the assumptions of the random errors a log likelihood function for the observed farm output is parameterized in terms of $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\lambda = \frac{\sigma_u^2}{\sigma_v^2}$ (Aigner et al., 1968).

However, this parameterization has a limitation since the variance, σ_u^2 refers to the variance of the untruncated random variable instead of the truncated half normal model. A different parameterization proposed by Battese and Corra (1977) helps solve the above problem. This new specification is given by;

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \text{ and } \gamma = \frac{\sigma_u^2}{\sigma^2} = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$$

The maximization of the appropriate log likelihood function gives the estimates of the model. These estimates are useful for testing the relevant hypothesis to validate the adequacy of the inefficiency model.

2.2.6 Incorporation of exogenous variables in the technical inefficiency model

The incorporation of exogenous variables in the technical inefficiency model can aid policy directives towards the achievement of the frontier output at a given technology and input level (Coelli and Battese, 1996). Some researchers tend to specify the exogenous variables to explain the performance of producers with variations in their respective

output and this can influence the production frontier relative to the efficiencies estimated for the producers. This is represented as;

$$\ln Y_i = \ln f(x_i, z_i; \beta) + v_i - u_i \quad i=1 \quad (2.15)$$

The disadvantage of this approach is that although it represents the production possibilities better it does not explain the inefficiency effects in an appropriate production model since they are assumed to be uncorrelated with the inefficiency effects (Kumbhakar and Lovell, 2000). A different approach incorporates the exogenous variables into the model and these are assumed to be correlated with the inefficiency effects. This approach is achieved in two stages. The first stage estimates a stochastic frontier model with the predicted technical inefficiencies as shown in equation 2.16 and the second stage involves the regressing of the exogenous variables on the inefficiency effects using (OLS) as shown in equation 2.17. This formulation however is a biased representation of the production frontier, because of the exclusion of the exogenous variables at the first stage. The second stage regression is a serious econometric problem because it breaks the no correlation assumption of the technical inefficiency effects with the socioeconomic variables (Kumbhakar and Lovell 2000).

$$\ln Y_i = \ln f(x_i; \beta) + v_i - u_i \quad i=1 \quad (2.16)$$

$$E(u_i / v_i - u_i) = g(z_i; \gamma) + \varepsilon_i \quad (2.17)$$

Adding the exogenous variables into the production process given in equation 2.18 in a deterministic perspective is an improvement upon earlier approaches.

$$\ln Y_i = \ln f(x_i; \beta) - \exp\{\gamma z_i\} + \varepsilon_i \quad (2.18)$$

This adjusts the efficiency scores quite appropriately because it allows for the explanation of inefficiency effects. It also solves the independence problem and reflects the nature of the production environment in which they are estimated. The major disadvantage of this model is that it does not allow for the effects of random noise in the production process. More recent approaches by Rafshneider and Stevenson (1991) takes into account the random noise effect in the model as well as it provides a solution to the problem of variable omission and interdependence problem in a single stage estimation procedure under varying distributional assumptions of the inefficiency effects when using the maximum likelihood estimation method. Huang and Liu (1994) specified the non-neutral stochastic frontier model which allows for the interaction between the exogenous variables and the conventional input variables. The non-neutral technical inefficiency model is specified below as;

$$\ln Y_i = \ln f(x_i; \beta) + v_i - g(z_i, x_i; \gamma) + \varepsilon_i \quad (2.19)$$

2.2.7 Review of empirical applications of the stochastic frontier analysis

Khair and Yabe (2011) conducted a study on the technical efficiency analysis of rice production in Vietnam using the stochastic frontier Analysis. The study sought to

measure the technical efficiency of rice production and identified some determinants of technical efficiency of rice farmers in Vietnam. The mean technical efficiency was estimated as 81.6 percent. The study demonstrated that the most important factors having positive impacts on technical efficiency levels were intensive labour in rice cultivation, irrigation and education.

Ahmadu and Alufohai (2012) also conducted a study on the estimation of technical efficiency of irrigated rice farmers in Niger state, Nigeria. Data analysis was done using the stochastic frontier production function and inefficiency model. The average technical efficiency of the farmers was estimated as 92 percent. A total of 60 irrigated rice farms were selected at random from the study area and were administered a structured pre-tested questionnaire. Results from the study indicated that household size significantly influenced technical efficiency positively. All the other factors like age, gender, education and farming experience were not significant.

Al-hassan presented a research paper to the African Economic Research Consortium, Nairobi (2008) on technical efficiency of rice farmers in Northern Ghana. Estimation was done using the stochastic frontier analysis. A two stage sampling technique was employed for this study, the first was a purposive selection of major rice producing districts, followed by a random selection of 252 irrigators and 480 non-irrigators from farm communities within each district. Results show that average technical efficiency of the irrigated farmers was 51 percent and that of the non- irrigators were 53 percent.

The main determinants of technical efficiency in the study area are education, extension contact, age and family size.

Abedullah et al. (2007) conducted a study on the analysis of technical efficiency of rice production in Punjab (Pakistan): implications for future investment strategies. The study employed a stochastic frontier production approach to determine the future investment strategies that can enhance the production of rice in Punjab. A total of 200 rice households were randomly selected, from 10 villages. Results indicate that the average technical efficiency was 91 percent. The determinants of technical efficiency include age and farm size which increase technical inefficiency and variables like education and tractor use reduce technical inefficiency.

Bäckman et al. (2011) conducted a study on determinants of technical efficiency of rice farms in north-central and north-western regions in Bangladesh. The paper estimated a quadratic stochastic frontier production function to examine the determinants of technical efficiency in rice farming in the study Area. The mean efficiency level was estimated as 83 percent. The parameter estimates showed that factors such as age, education, number of plots, region (dummy variable), access to microfinance (dummy variable), and off-farm income were positively related with inefficiency while extension visits and experience were negatively related to inefficiency.

Ologbon et al. (2012) conducted a study on adoption of 'Ofada' rice variety and technical efficiency of rice-based production systems in Ogun State, Nigeria. Primary data were

collected in a two-stage sampling procedure and analysed for 105 rice farmers selected from ten (10) prominent rice-producing communities in the study area. Probit and Gross margin models were used to estimate the determinants of adopting the improved “Ofada” rice variety and the profitability of the rice enterprise, respectively, while farmers’ production efficiency was measured using the stochastic frontier model.

A mean of 84.3 percent was recorded. Results also indicated that variables such as farmers’ age and loan obtained had a positive effect on inefficiency although their impact was weak, whilst other factors like years of experience had significant and negative effect on farmers’ inefficiency.

Donkoh et al. (2013) conducted a study on the technical efficiency of rice production at the Tono Irrigation Scheme in Northern Ghana. One-step estimation of the stochastic frontier model was employed. Data was collected in during the 2007/2008 farming season at the Tono Irrigation Project located in the Kassena-Nankana District of Upper East Region of Ghana. The choice of the study area was purposive. Stratified sampling technique was used to divide the population into males and females. Simple random sampling was then used to select the final respondents based on their availability as at the time of data collection. Semi-structured questionnaire was the main tool used for the data collection. The average technical efficiency was estimated at 81 percent. The factors that determined farmers’ technical efficiency included education and the sex variable.

Bokusheva and Hockmann (2006) conducted a study on production risk and technical inefficiency in Russian agriculture. The study sought to investigate production risk and

technical inefficiency as two possible sources of the production variability. A production function specification accounting for the effect of inputs on both risk and technical inefficiency was used to describe the production technologies of the Russian farms. The empirical analysis was conducted using panel data from 1996 to 2001 on 443 large agricultural enterprises from three regions in central, southern and Volga Russia.

The estimates indicate that there are significant differences in production technologies in the three investigated regions. This holds not only for the production elasticities but also for the impact of technical change. Whereas in Oreol and Krasnodar a shift of the production frontier was hardly observed, Samara experienced more dynamic change that has apparently significantly enhanced its production possibilities. Farm efficiency in Oreol and Krasnodar increased significantly between 1996 and 2001. However, the farms in Samara were less successful in adjusting to the best regional practice in that period.

Wan G.H and Battese G.E (1992) presented a paper on a stochastic frontier production function incorporating flexible risk properties. The paper sought to throw more light on a stochastic frontier production function which permits the marginal production risks of inputs to be negative or positive and the technical efficiency of firms to be a function of the levels of the factor inputs. The paper further concluded that stochastic frontier production function presented in the paper has flexible production risks which are desirable for the analysis of data on different production systems. The paper also proposed that the model be extended for the analysis of panel data and also permit time-varying technical inefficiencies of production.

Kumbhakar (2002) presented an article in the Oxford journals on specification and estimation of production risk, risk preferences and technical efficiency. The article deals with specification and estimation of risk preferences, production risk, and technical inefficiency. The article makes contribution in three separate areas of production economics. First, it models producers' attitude toward risk and derives risk preference functions (without assuming any parametric form of the utility function and any distribution of the error term representing production risk) when risk arises from production uncertainty and technical inefficiency. Secondly, in this article the standard production risk model is extended to accommodate technical inefficiency and producers' attitude toward risk. Finally, the technical efficiency model is generalized to accommodate production risk and producers' attitude toward risk.

Ogundari and Akinbogun (2010) conducted a study on modeling technical efficiency with production risk: A study of fish farms in Nigeria. Data from a total of 64 fish farms randomly sampled from Oyo State, Nigeria. The study employed the stochastic frontier model with flexible risk specification. The empirical findings show that the mean fish output is significantly influenced by labor, fertilizer, and feed. Fertilizer and feed are found to be risk-increasing inputs, whilst labour is revealed to be a risk-reducing input. Furthermore, it is revealed that labour, farming experience, education, and access to market significantly decreases the technical inefficiency of farmers. Mean technical efficiency was estimated as 79 percent.

Asche and Tveteras (1999) conducted a study on modeling production risk with a two-step procedure. This study deals with modeling of production risk by means of a two-step procedure. The study does not immediately adopt restrictive functional forms for the risky production technology. The mean and risk functions are estimated separately. This allows the use of more flexible functional forms for both the mean and the risk functions than commonly found in the literature. An empirical application to Norwegian salmon farming, where restrictive specifications of the technology are rejected. The data was collected from the Norwegian Directorate of Fisheries' annual survey of fish farms. There was a total of 1,953 observations on 372 farms observed from three to nine years during the period 1985-93. The input factor feed is found to be the most important output in terms of output elasticity, followed by fish input with. Labour, capital, and material inputs all have a risk-decreasing effect, while both fish feed and fish input have a risk-increasing effect.

Rahman et al. (2012) conducted a study on a stochastic frontier approach to model technical efficiency of rice farmers in Bangladesh: An Empirical Analysis. The study estimated the farm-size-specific productivity and technical efficiency of all rice crops. Farm-size-specific technical efficiency scores were estimated using stochastic production frontiers. Fertilizer, manure, irrigation cost, insecticide cost, area under production and experience were important factors to increase production. Average technical efficiency for large, medium, small, marginal and all farms were respectively 0.88, 0.92, 0.94, 0.75 and 0.88. In the technical inefficiency effect, age, education and

family size had positive impact on efficiency effect, whereas land under household had negative impact on efficiency effect.

Villano and Fleming (2006) conducted a study on technical inefficiency and production risk in rice farming: Evidence from Central Luzon Philippines. The study uses a stochastic frontier production function with a heteroskedastic error structure. An 8-year panel dataset collected from 46 rain fed rice farmers was used to estimate flexible functional specifications. Over the whole period, the average technical efficiency was found to be 79 percent. Mean output was significantly influenced by area planted to rice, labor and the amount of fertilizer used. Consequently, these inputs were found to be risk-increasing, whereas herbicide was found to be a risk-reducing input. According to the study the determinants that enhance technical efficiency include education and the age ratio.

Onumah et al. (2010) conducted a study on elements which delimitate technical efficiency of fish farms in Ghana. The stochastic frontier function was employed. Three regions of Ghana including Ashanti, Eastern and Greater Accra were chosen for the study based on the concentration of fish farmers, and 50 farms from each region were randomly selected making a total of 150 farmers selected in all. Mean technical efficiency was estimated to be 84 percent. The technical inefficiency model demonstrates that age and experience are estimated to be significantly positive. Variables like gender, pond type, occupation, landownership, extension service are estimated to be significantly negative.

All the empirical review that has been outlined in this study sought to calculate technical efficiency in mostly rice farms. Khai and Yabe (2011) demonstrated that the most important factors having positive impacts on technical efficiency levels are intensive labour in rice cultivation, irrigation and education with mean technical efficiency of 81.6 percent. Ahmadu and Alufohai (2012) recorded an average technical efficiency of the 92 percent. Results from the study indicated that household size significantly influenced technical efficiency positively. A study done by Al-hassan (2008) shows that the average technical efficiency of the irrigated farmers was 51 percent and that of the non- irrigators were 53 percent. The main determinants of technical efficiency in the study area are education, extension contact, age and family size. Results from Abedullah et al. (2007) also indicates an average technical efficiency was 91 percent. The determinants of technical efficiency included age and farm size which increase technical inefficiency and variables like education and tractor use reduce technical inefficiency. Ologbon et al. (2012) reported a mean technical efficiency of 84.3 percent.

Results also indicated that variables such as farmers' age and loan obtained had a positive effect on inefficiency although their impact was weak, whilst other factors like years of experience had significant and negative effect on farmers' inefficiency. For the study done by Donkoh et al. (2013) the average technical efficiency was estimated at 81 percent. The factors that determined farmers' technical efficiency included education and the sex variable. Ogundari and Akinbogun (2010) found fertilizer and feed to be risk-increasing inputs, whilst labour was revealed to be a risk-reducing input.

Furthermore, it is revealed that labour, farming experience, education, and access to market significantly decreases the technical inefficiency of farmers and the mean technical efficiency was estimated as 79 percent. Asche and Tveteras, (1999) found that the input factor feed was found to be the most important output in terms of output elasticity, followed by fish input with labour, capital, and material inputs all have a risk-decreasing effect, while both fish feed and fish input have a risk-increasing effect. Rahman et al. (2012) reported an average technical efficiency for large, medium, small, marginal and all farms as 0.88, 0.92, 0.94, 0.75 and 0.88 respectively. In the technical Inefficiency effect, age, education and family size had positive impact on efficiency effect, whereas land under household had negative impact on efficiency effect. Villano and Fleming (2006) also recorded an average technical efficiency of 79 percent.

Mean output was significantly influenced by area planted to rice, labor and the amount of fertilizer used. Consequently, these inputs were found to be risk-increasing, whereas herbicide was found to be a risk-reducing input. According to the study the determinants that enhance technical efficiency include education and the age ratio. Onumah et al. (2010) recorded a mean technical efficiency of 84 percent for fish farms in Ghana. Results demonstrated that age and experience were significantly positive. Variables like gender, pond type, occupation, landownership, extension service were estimated to be significantly negative.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This section presents details about the method of analysis i.e. conceptual framework, theoretical framework, empirical analysis for estimating technical efficiency and production risk and the hypothesis tested. It also outlines the data and sampling technique employed and information about the study area.

3.2 Method of Analysis

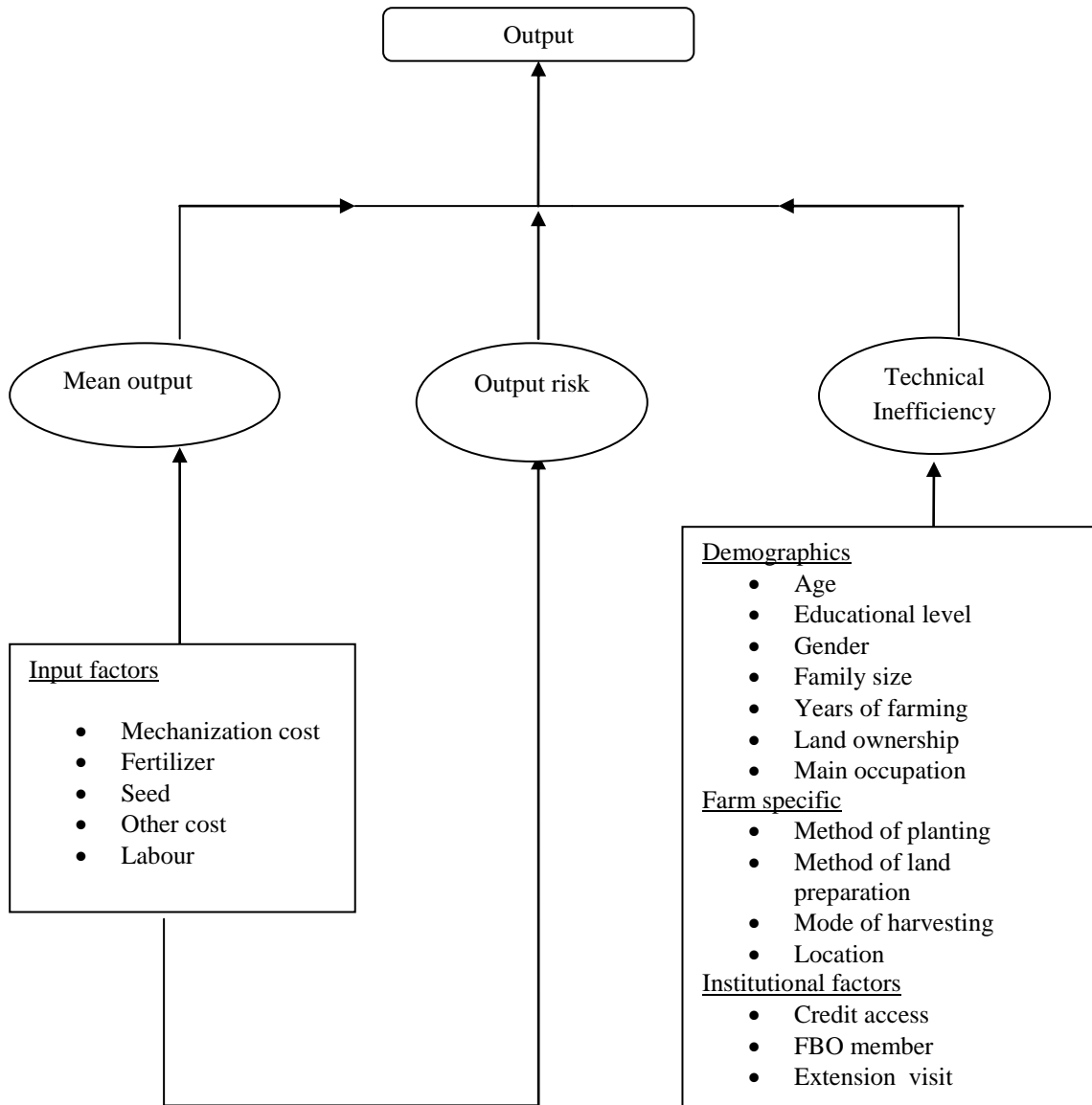
This study adopts descriptive statistics in the form of frequencies and tables to describe the socio-economic characteristics of respondents. It also employs the stochastic frontier technique whilst adopting the single stage maximum likelihood estimation. The STATA 12 software was used for the analysis.

3.2.1 Conceptual framework

This study conceptualises that output realized consists of three components namely, the mean output function, the production risk and the technical inefficiency components (Figure 3.1). The concept for this study is consistent with the production function stated by Kumbhakar (2002) which allows for production risk and technical inefficiency to be estimated simultaneously in the stochastic frontier analysis. The input factors i.e. fertilizer, mechanization cost, seed, other cost and labour are considered to influence both

the mean output and output risk. The factors that influence technical efficiency can be grouped into three categories namely demographic, farm specific and institutional factors.

Figure 3.1: Conceptual framework



Source: Author's construct

The demographic factors include: age, educational level, gender, family size, years of farming, landownership and main occupation. The farm specific factors include: method of planting, method of land preparation, mode of harvesting and location. The institutional factors covers credit access, farmer based organization member and extension visit.

3.2.2 Theoretical Framework for the Stochastic Production Frontier Model

Following Kumbhakar (2002) the production process is represented below as;

$$Y_i = f(x_i; \alpha) + g(x_i; \psi)v_i - q(x_i; Z)u_i \quad (3.1)$$

Y_i refers to the observed output produced by the i -th farm, $f(x_i; \alpha)$ is the mean output function, $g(x; \psi)$ is the output risk function, x_i 's, are the input variables, α is the estimated coefficients of the mean output function, ψ is the estimated coefficients of production risk function, $q(x_i; Z)$ represents the technical inefficiency model, Z is the estimated effect of the explanatory variables in the technical inefficiency model, v_i , represents the random noise in the data and u_i represents farm specific technical inefficiencies. Technical efficiency of the i -th farm is the ratio of observed output given the values of its inputs and its inefficiency effects to corresponding maximum feasible output if there were no inefficiency effects (Battese and Coelli, 1998).

The technical efficiency of the i 'th farm is given by equation:

$$TE_i = \frac{E(Y_i / X_i, U_i)}{E(Y_i / X_i, U_i = 0)} = \frac{f(x_i; \alpha) - g(x_i; \psi)u_i}{f(x_i; \alpha)} = 1 - \frac{ug(x_i; \psi)}{f(x_i; \alpha)}$$

(3.2)

$$TI_i = \frac{ug(x_i; \psi)}{f(x_i; \alpha)} \quad (3.3)$$

$$TE_i = 1 - TI_i \quad (3.4)$$

Where TI is technical inefficiency. Given the values of the inputs, and the inefficiency effects, U_i , the mean output of the i -th farmer is given by:

$$E(Y_i / X_i, U_i) = f(X_i; \psi) - g(X_i; \psi)U_i \quad (3.5)$$

The variance of output or production risk is given by,

$$\text{Var}(Y_i / X_i, U_i) = g^2(X_i; \psi) \quad (3.6)$$

The marginal effect of the input variables on the production risk is given below;

$$\frac{\partial \text{var}(Y_i)}{\partial X_i} = \frac{\partial g^2(X_i; \psi)}{\partial X_i} = 2g(X_i; \psi)g_i(X_i; \psi) \quad (3.7)$$

Thus,

$$\frac{\partial g^2(X; \psi)}{\partial X_i} < 0 \Rightarrow \text{risk decreasing of the } i\text{'th input ,}$$

$$\frac{\partial g^2(X; \psi)}{\partial X_i} > 0 \Rightarrow \text{risk increasing of the } i\text{'th input}$$

The marginal effect of the i -th input on production risk is positive or negative depending on the signs of $g(x_i; \psi)$, and $g_i(x; \psi)$, where the latter is the partial derivative of the production risk function with respect to the i -th input. If the marginal risk is positive it means that input is risk increasing and if the marginal risk is negative it means that the input is a risk decreasing.

3.2.3 Empirical Model Specification

For any empirical study, the choice of a functional form is vital because the chosen functional form can significantly influence the parameter estimates (Tewodros, 2011). There are generally two functional forms of the stochastic frontier model that are often used; the Cobb-Douglas and the translog functional forms. Studies that have employed the Cobb-Douglas production include Khai and Yabe (2011), Ahmadu and Alufohai (2012), Rahman et al. (2012). The Cobb-Douglas functional form is easy to implement however it imposes a severe restriction on the production elasticities to be constant and the elasticities of input substitution to be equal to one. Other studies that adopted the translog functional form also include Abedullah et al. (2007), Donkoh et al. (2013), Ogundari and Akinbogun (2010) and Onumah et al. (2010). The translog functional form is known to be less restrictive, allowing for the combination of squared and cross product

terms of the explanatory variables with the view of obtaining goodness of fit of the model.

In this study, the translog model of the production function is used and specified as;

$$\ln Y = \beta_0 + \sum_{i=1}^5 \beta_j \ln x_{ij} + 0.5 \sum_{i=1}^5 \sum_{k=1}^5 \beta_{jk} \ln x_{ij} \ln x_{ki} + \varepsilon_i \quad (3.8)$$

Where the error term, ε_i , is specified as;

$$\varepsilon_i = g(x_i; \psi) - q(x_i; Z_i) \quad (3.9)$$

$g(x_i; \psi)$ is the risk component and $q(x_i; z_i)$ is the technical inefficiency component.

Elasticity

The elasticities of output with respect to the different inputs are functions of the level of inputs involved and generally expressed as:

$$\frac{\partial \ln E(Y_i)}{\partial \ln X_{ji}} = \left\{ \beta_j + \beta_{jj} \ln X_{ji} + \sum_{k \neq j} \beta_{jk} \ln X_{ki} \right\}$$

However, when the output and input variables have been normalized by the respective sample means, the first-order coefficient can be interpreted as elasticities of output with respect to the different input (evaluated at the variable means). For this study, the output and input variables have been normalized using the standardized mean method, the first-order coefficients of the input variables can therefore be interpreted as elasticities of

output. The sum total of the output elasticities is the estimated scale elasticity (ε) which is defined as the percentage change in output as a result of 1 percent change in all input factors. The scale elasticity measures the returns to scale for the sampled rice producers. Scale elasticity greater than one indicates an increasing returns to scale. An estimate less than one indicates a decreasing returns to scale, while an estimate equal to one indicates a constant return to scale. The input variables used in this study are labour, seed, fertilizer, other cost and mechanization cost.

Description of variables used in the study

Output (Y) of rice is measured as the quantity of rice produced in kilograms during the 2011/2012 production year.

Seed (X_1) is a measure of the quantity of rice seed in kilograms used by the i-th farmer for the production year.

Labour (X_2) is measured as the total man-days employed by the i-th farm during the production year. Hired and family labours were assumed to be equally productive and were aggregated. Man days for labour was calculated as; one adult male working for one day (8 hours) equals one man day; one female and one child (< 18years) working for one day (8 hours) equals 0.75 and 0.5 man days respectively. Classifications are based on similar works done by Coelli and Battese (1996) and Onumah et al. (2010).

Fertilizer (X_3) refers to the quantity of chemical fertilizer used by i-th farmer for the production year, measured in kilograms.

Other cost (X_4) captures irrigation cost, cost of agrochemicals, the cost of other services (e.g. cutting, threshing and milling) incurred in the production year and the depreciation on fixed assets.

Mechanization cost (X_5) refers to the mechanization cost incurred in the production year. Mechanization is a very important factor in rice production which tends to directly affect mean output and hence its influence on mean output and output variability needs to be investigated.

Table 3.1 shows the variables in the mean output function and their prior expectation.

Labour, seed, fertilizer, other cost and mechanization cost are expected to increase mean output

Table 3.1: variables in the mean output function and their A priori expectation

Variable	Description	A priori expectation
X_1	Labour	+
X_2	Seed	+
X_3	Fertilizer	+
X_4	Other cost	+
X_5	Mechanization cost	+

Production risk

The linear production risk function is specified as;

$$g(x_i; \psi)v_i = \psi_0 + \sum_{m=1}^5 \psi_m x_{mi} \quad (3.10)$$

Where x_i 's represent the input variables, ψ_m 's are the estimated risk model parameters and the v_i 's are the pure noise effects, X_{1i} denotes labour measured in man-days,

X_{2i} denotes seed measured in kilograms, X_{3i} denotes quantity of fertilizer measured in kilograms, X_{4i} denotes other cost measured in cedis, X_{5i} denotes mechanization cost measured in cedis.

The Ψ_m 's are the marginal production risks of the individual inputs and if it is positive it means that the respective input is a risk increasing input. Where Ψ_m becomes negative it means that that respective input reduces output variance.

The input factors i.e. labour, seed, fertilizer, other cost and mechanization cost can either increase production risk or decrease it.

Table 3.2: variables in the production risk function and their A priori expectations

Variable	Description	A priori expectation
X_1	Labour	+/-
X_2	Seed	+/-
X_3	Fertilizer	+/-
X_4	Other cost	+/-
X_5	Mechanization cost	+/-

Technical Inefficiency

The linear technical inefficiency model is given as;

$$q(z_i; \delta_i) = \delta_0 + \sum_{j=1}^{14} \delta_n Z_{ni} \quad (3.11)$$

Where z_i 's are the exogenous explanatory variables and the δ 's are the estimated coefficients of the technical inefficiency model.

The exogenous variables are: age, education, credit access, extension visits, gender, years of farming, landownership, family size, member of a farmer based organization main occupation, method of planting (transplanting only), method of land preparation, mode of harvesting, regional effect.

The variable **age** (Z_{1i}) is measured in years.

Education is (Z_{2i}) measured in levels, a farmer who has no education is assigned 0, a farmer with a primary level education is assigned 1, junior high school level, 2, secondary school level, 3, tertiary level, 4.

Credit Access (Z_{3i}) is a binary variable used to capture the effect of credit on the efficiency of farmers, this variable is measured as a dummy, 1 if farmer had access to credit, 0 if they didn't during the 2011/2012 production year, access to credit includes both partial and adequate credit level received.

The **extension visit** (Z_{4i}) variable was measured as a dummy, 1 was assigned to farmers who had interactions with the extension agent during the production year to solicit for advice, and 0 was assigned to farmers who had no contact with the extension agent during the course of the production year.

The variable **gender** (Z_{5i}) is measured as dummy, 1 was assigned to male farmers and 0 to female farmers.

Years of farming (Z_{6i}) was measured as the number of years that the farmer has been engaged in rice farming.

Landownership is (Z_{7i}) measured as a dummy, 1 for a farmer who was originally allotted the land by the irrigation scheme management, 0 for a farmer operating on a rented land.

The **family Size** (Z_{8i}) variable tries to capture the number of people (adult men and women and children) who are living with the farmer during the cropping year.

The variable **member of a farmer based organization** (Z_{9i}) is measured as a dummy; if the farmer is a member of a farmer based organization he is assigned a value of 1 and 0 if he is not.

The variable **main Occupation** (Z_{10i}) is measured as a dummy, 1 was assigned to farmers whose main occupation is rice farming, 0 was for farmers who had occupations as a main occupation.

The method of planting employed is (Z_{11i}) measured as a dummy, 1 assigned to farmers who employed the transplanting method only for the production year and 0 for broadcasting method only.

The method of **land preparation** (Z_{12i}) is also measured as a dummy, 1 assigned to farmers who used a tractor hitched with a plough for tillage and 0 for those who used power tillers.

The **mode of harvesting** (Z_{13i}) is measured as a dummy, 1 for farmers who employed the use of combined harvesters for harvesting and 0 is for farmers who did manual harvesting.

The **regional effect variable** (Z_{i14}) was introduced to investigate regional effect on efficiency. 1 was assigned to Greater Accra Region and 0 for Volta region.

Table 3.3: Exogenous variables in the inefficiency models and their A priori expectations

Variable	Description	A priori expectation
Z ₁	Age	-
Z ₂	Education	-
Z ₃	Credit Access	-
Z ₄	Extension visits	-
Z ₅	Gender	-
Z ₆	Years of farming	-
Z ₇	Landownership	-/+
Z ₈	Family Size	-
Z ₉	Member of FBO	-
Z ₁₀	Main Occupation	-
Z ₁₁	Method of planting	-
Z ₁₂	Method of land preparation	-/+
Z ₁₃	Mode of harvesting	-
Z ₁₄	Regional effect	-/+

3.2.4 Statement of Hypothesis

The following hypothesis were formulated to ascertain the appropriateness of the functional form for the data, to determine whether production risk in inputs and technical inefficiency significantly explain output variability, whether the exogenous variables and the conventional input variables in the technical inefficiency model explains the technical inefficiency and whether there is regional effect on technical efficiency of production.

1. $H_o : \beta_{jk} = 0$, the coefficients of the second-order variable in the translog model are zero. This implies that the Cobb-Douglas function is the best fit for the model.
2. $H_o : \psi_1 = \psi_2 = \dots \psi_n = 0$, the null hypothesis that output variability is not explained by production risk in input factors.

3. $H_0 : \lambda = 0$, the null hypothesis specifies that inefficiency effects are absent from the model at every level. The variance of the inefficiency term is zero; the exogenous factors should be incorporated into the mean output function and estimated using ordinary Least Square. However, if $\lambda > 0$, it means that the technical inefficiency effects are present in the model and hence the stochastic frontier model must be employed.
4. $H_0 : \delta_1 = \delta_2 = \dots = \delta_{14} = 0$, the null hypothesis that farm specific factors do not jointly influence technical efficiency in the model.
5. $H_0 : \delta_{14} = 0$, the null hypothesis that there is no regional effect on technical efficiency of production.
6. $H_0 : \bar{\chi}_G = \bar{\chi}_V$, the null hypothesis that the mean technical efficiency for Greater Accra Region is the same as that of Volta Region. Where
 $\bar{\chi}_G$ = Mean technical efficiency of irrigated rice farms in Greater Accra region
and $\bar{\chi}_V$ = Mean technical efficiency of irrigated rice farms in Volta Region.

The entire hypothesis with the exception of the sixth one (i.e. the difference in mean technical efficiency) was investigated using the generalized likelihood-ratio statistic (LR) which is given by:

$$LR = -2[\ln \{L(H_0)\} - \ln \{L(H_1)\}], \quad (3.12)$$

where: $L(H_0)$ and $L(H_1)$ are values of likelihood function under the null (H_0) and alternative (H_1) hypothesis, respectively. LR has approximately a Chi-square distribution if the given null hypothesis is true with a degree of freedom equal to the number of parameters assumed to be zero in (H_0). The third hypothesis however assumes a mixed chi-square distribution hence Table 1 of Kodde and Palm (1986, p.1246) is used. The difference in mean technical efficiency is investigated using a t-test.

3.3 Data and Sampling Technique

The study was conducted in 2 geographical regions of the southern sector of Ghana namely: the Greater Accra and Volta Regions. These 2 regions were selected for this study based on the relative concentration of irrigated rice farms present. The Volta region and the Greater Accra region record the highest concentration of irrigated rice farms in the southern sector. The selected districts where irrigated rice production is practiced more intensively in the study area are the Dangme West district and the Ketu North district. The Afife irrigation project alone covers an expanse of 880 hectares out of the total of 990 hectares of arable land making it the largest GIDA rice irrigation scheme in the entire region. The Kpong Irrigation project also has a total arable land of about 3000 hectares of which 2800 is cultivated under the irrigation scheme. This irrigation scheme is the largest GIDA irrigation scheme in the Greater Accra Region. In this study, cross sectional data was collected from 356 irrigated rice farms under the 2 schemes. Following the formula in calculating sample size as proposed by Yamane (1967)

Based on the population of irrigated rice farms in the study area the sample size is calculated as:

$$n = \frac{N}{1 + N(e)^2}$$

n= sample Size

N= population Size

E=level of precision

Given:

N (2800+880) =3,680 farms

e=0.05 (95% confidence interval)

$$n = \frac{3680}{1 + 3680(0.05)^2}$$

=361 farms in all

Based on relative concentration of irrigated rice farms in the two regions Volta region

sample size = $\frac{880}{3680} \times 361 = 86$ farms, Greater Accra sample size $\frac{2800}{3680} \times 361 = 275$ farms.

In anticipation of possible data collection problems 91 farms were captured in the Volta region and for the Greater Accra region 275. However 10 of the responses had to be taken out during the Data cleaning process for purposes of data quality. In total the responses of 91 farms in the Volta region and 265 farms in the Greater Accra Region have been captured in this study. Farmers were interviewed using a structured questionnaire on a one on one interview basis. A pilot survey was first conducted to test the applicability of the questionnaire to the study area and adjustments were made

accordingly before the official commencement of data collection. Information obtained includes output and input variables, socio economic and farm specific factors.

A total of 356 irrigated rice farms were randomly selected from these two irrigation schemes. Based on relative proportions, 91 farmers were randomly selected from the Afife irrigation project. A total of 265 farms were also selected from the Kpong irrigation

3.4 Study Area

This research study used primarily farm level data. Irrigated rice farms that were being fully managed by the Ghana Irrigation development authority in the Greater Accra and Volta regions were interviewed. For the Greater Accra region, irrigated rice farms in the Dangme West District were interviewed as this district records the largest concentration of irrigated rice farms in the entire region. For the Volta Region the Ketu- North district was also selected based on the concentration of irrigated rice farms in the district.

3.4.1 Dangme West

The Dangme West District is situated in the Southeastern part of Ghana, lying between latitude 5° 45' south and 6° 05' North and Longitude 0° 05' East and 0° 20' West. It is the largest of the six districts in the Greater Accra Region. It has a total land area of 1,442 square kilometers representing 41.5 percent of the regional land area. The district shares boundaries with the Yiolo Krobo District on the North-West, North-Tongu District on the North-East, Akwapim-North District on the west, Tema District on the South-west and Dangme-East District on the East. The north-eastern and the southern portions of the

district are washed by the Volta river and the Atlantic Ocean respectively with a coastline stretching over 37 kilometers. The District is further split into 299 communities. The major communities include Dodowa (District Capital), Prampram, Ningo, Asutsuare, Dawhenya, Afiencya, Ayikuma, Kordiabe, Agomeda, Doryumu, Osuwem, etc. The main rice growing areas are Asutsuare and Dawhenya. The vegetation is mainly coastal savannah with a small transitional zone along the foothills of the Akwapim Range. The soil type is mainly of the heavy Akuse series with sandy and sandy-loams in certain areas. The rainfall pattern is bimodal and the main agricultural activities undertaken are livestock and crop production, fish production, fishing and fish processing and other agro-processing activities. Agriculture employs 58.6 percent of the entire population followed by trading which does the next largest employer constitute 22.1 percent of the population. The district also abounds in natural resources that could be harnessed for increasing production and gainful employment. The largest developed land area for rice production under irrigation in the Greater Accra region is found in this district specifically in Asutsuare (The Kpong irrigation Scheme, KIS). Covering an expanse of approximately 2800 hectares.

The Kpong irrigation Scheme

The Kpong irrigation scheme was constructed with African Development Bank (AFDB) funding in the late 1990s. It derives water from Volta River via the Kpong Reservoir which is primarily a relatively low head hydroelectric generation and storage facility. The land is officially allocated to the farmer beneficiaries in one hectare allocations. These beneficiaries are obliged to be members of the farmers' cooperative that is mostly

involved in managing credit through the local branch of the Agriculture Development Bank. i.e. the Osudoku Agricultural co-operative.

3.4.2 Ketu North District

For the Volta region the largest developed land area under irrigation which is being fully managed by GIDA is located at Afife (AIP). It covers a total of about 880 hectares. The rainfall distribution is bimodal giving a major period between March and June and minor season between September and November. The Ketu North District is one of the 25 Districts in the Volta Region of Ghana with Dzodze as its capital. The District covers a land area of 754 km² with an estimated population of 83,161 as at the year 2000. This has been projected to be 98,571 in 2010. The Ketu North district is noted widely in the West African sub region for its production and marketing of exclusive quality palm oil, gari and the famous Afife rice (Togo Marshal). The original vegetation of the District is Savannah woodland made up of short grassland with small clumps of bush and trees as well as Mangrove forests in the marshlands are found in the District. However, the extensive farming activities in the district have, over the years, reduced the natural vegetation. The largest rice irrigation scheme is the Afife Irrigation project, which is under the management of Ghana Irrigation Development Authority and the developed area under production is 880 hectares out of the total land size of 990 hectares.

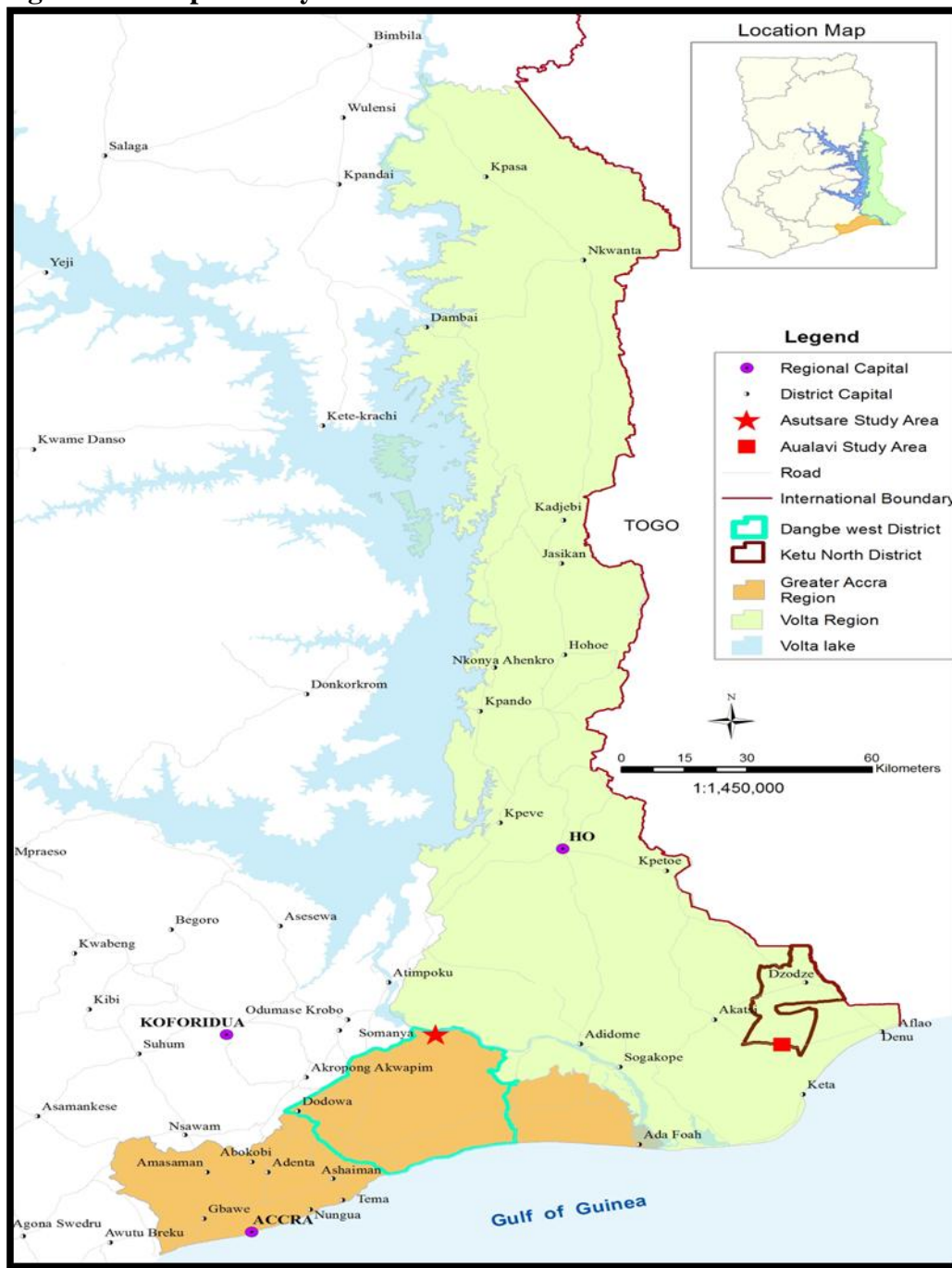
Afife/Weta Irrigation project

The Afife Irrigation Project is located in the Avalavi community in the ketu north district of the Volta region of Ghana. The project consists essentially of two (2) earthen dams

situated on the lower reaches of the Agali and Kplikpa rivers that deliver water to the field by gravity. The Agali reservoir was constructed by the Soviets and later rehabilitated in 1982 by the Chinese of the People's Republic of China during the construction of the Kplikpa reservoir. The gross area is 950 ha and the net land area under irrigation is about 880 ha. The vegetation is mainly coastal shrub and grassland.

The Ketu North District is one of the 18 Districts in the Volta Region of Ghana with Dzodze as its capital. The district covers a land area of 754 square km with an estimated population of 98,571 as at 2010. The Ketu North district is noted widely in the West African sub region for its production and marketing of exclusive quality palm oil, gari and the famous Afife rice (Togo Marshall).

Figure 3.2: Map of study Area



Source: Department of Geography, University of Ghana.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussions of the study. It captures productivity analysis, production risk function estimates, the prediction of technical inefficiency estimates and the determinants of technical efficiency. This chapter also presents the results from the various hypotheses that were tested.

4.2 Summary Statistics of the Output and Input Variables

The average yield of the study area is 4,559.75 kg per hectare i.e. 4.56MT/HA (Table 4.1). This is higher than the national average of 2.71MT/HA but lower than the Greater Accra Regions' mean yield of 5.48MT/HA (Boadu, 2011). The variable other cost captures irrigation cost, depreciation on fixed assets, cost of Agrochemicals and cost of other services e.g. cutting, milling threshing. According to Table 4.1, the minimum rice yield obtained was 1,333kg per hectare and the maximum is 10,764.71kg per hectare. Seed, labour, fertilizer and other cost and mechanization cost are important input factors in the rice production process. The average farm size was 2 hectares. The minimum quantity of rice seed used was 15kg per hectare and the maximum 397 kg per hectare. Labour was measured in man-days with the minimum quantity of labour employed during the production year being 5.96 man-days per hectare and a maximum of 160.78 man-days per hectare. The minimum quantity of fertilizer used was 85.71 kg per hectare and the maximum was 4500 kg per hectare. The lowest cost incurred on irrigation, agrochemicals depreciation and other services is GHC 63 and the highest being GHC

5414.96. The average cost spent on mechanization is GHC 521.35. The rice farmers in the study area use different combinations of NPK 15:15:15, Sulphate of Ammonia, Sulphan, Activa and Urea fertilizers for cultivation. The 356 farmers that were interviewed in the study Area were all cultivating improved aromatic varieties. Farmers in the Greater Accra region cultivate varieties such as Jasmine 85, Jet 3 and Aromatic short. The bulk of farmers in the Volta region on the other hand as at the time of data collection were mainly into the cultivation of the variety Togo mashall with just 1 farmer trying out the jasmine 85 variety. However it must be mentioned that as at the time of collecting the data in the Volta Region the management of the irrigation scheme were conducting a pilot test to see how well other aromatic varieties like jasmine 85 and Aromatic short will thrive on the farm.

Table 4.1 Summary Statistics of the Output and Input Variables

Variable	Variable Definition	Mean	Standard Deviation	Minimum	Maximum
Output	Kg per Ha	4,559.75	1391.15	1333.33	10764.71
Labour	Man-days per Ha	44.45	25.52	5.96	160.78
Seed	Kg per Ha	130.78	56.61	15.00	397.06
Fertilizer	Kg per Ha	650.29	443.88	85.71	4500.00
Other cost	GHC per Ha	803.310	690.854	63.000	5414.958
Mechanization cost	GHC per Ha	521.35	580.717	23.000	6975

Source: Field Survey (2012)

4.3 Socioeconomic Characteristics of farmers

The socio economic profile of the farmers is presented in Table 4.2. The average number of people in a rice producing farmer household is 5. A study by Al-hassan (2008) on technical efficiency of rice farmers in Northern Ghana recorded a higher average household number of 9. Results from this study further shows that 60 percent of the farmers had attained at least a Junior high school or senior high school level of education. This result is also consistent with the work done by Donkoh et al. (2013) on the technical efficiency of rice production at the Tono Irrigation Scheme in Northern Ghana. The mean education level attained was Senior high school. Al-hassan (2008) on the other hand recorded a rather low mean literacy level of a primary school education. This implies that the level of literacy is specific to a particular location and may not necessarily be tied to rice cultivation. Out of a total 356 farmers interviewed 67.4 percent were the original land owners with the remaining 32.6 percent cultivating on rented land.

The average number of extension contacts that the farmers have had is 2.61. This is also consistent with Al-hassan (2008) who finds that the mean number of extension contact for irrigators was 3 and the mean value for the overall sample was 4. Results further show that rice farming in the study area is dominated by males with a proportion of 73.9 percent and 26.1 percent representing females. This result is consistent with the study by Ahmadu and Alufohai (2012) on the estimation of technical efficiency of irrigated rice farmers in Niger state, Nigeria. It was estimated that 87 percent of the farmers were males with only 13 percent representing females. The mean age of the farmers is estimated as 44 years with 51.1 percent of the famers being less than or equal to the mean age. This implies that the rice cultivation industry is dominated by the young active work

force mainly because of its labour intensive nature. The results obtained for the mean age is to a large extent consistent with the work done by Al-hassan (2008) on technical efficiency of rice farmers in Northern Ghana where the mean age for the entire sample of rice farmers was 42 years. The work done by Abedullah et al. (2007) on the analysis of technical efficiency of rice production in Punjab (Pakistan) also reported a mean age of 49 years. Findings indicate that approximately half of the entire sample (52) belonged to a farmer based organization.

A greater proportion (90.2 percent) of the farmers were engaged in rice farming as a main occupation indicating that rice farming is the main source of income generation in the study Area. Only 23.3 percent of the farmers employed the transplanting method as a method of planting for the production year. A proportion of 30.1 percent of the farmers employed the use of a tractor hitched with a harrow for tillage during land reparation. Nearly 87 percent of the farmers did manual harvesting. According to table 4.2 the average number of years that the farmers have been engaged in rice farming is 9.81 years. Al-hassan (2008) recorded mean years of farming experience for irrigators as 10 years. The work by Donkoh et al. (2013) on the technical efficiency of rice production at the Tono irrigation scheme in Northern Ghana also recorded the mean years of farming experience as 11 years. This clearly indicates that in Ghana rice cultivation has been a thriving source of livelihood.

Table 4.2 Descriptive statistics of demographic characteristics of respondents

Variable	Variable definition	Minimum	Maximum	Mean	Std. Deviation
Age(Yrs)	Number of years	25	75	44.11	8.236
Educational Level	No schooling=0 Primary level=1 Junior High School=2 level/Middle School=3 Senior High School level=4 Vocational School=5 Tertiary Level=6	0	6	2.02	1.126
Credit Access	Access to credit=1 No Access=0	0	1	.42	.495
Extension	Number of extension contact	0	9	2.61	1.975
Gender	(1=Male,0=Female)	0	1	.74	.440
Years of farming	Number of years engaged in rice farming	1	35	9.81	6.057
Landownership	Own land=1 Rented land=0	0	1	.67	.469
Family Size	Number of people in the farmer household	0	15	4.95	2.106
Member of a farmer based organization	Yes=1 No=0	0	1	.52	.500
Rice farming as a main occupation	Main Occupation=1 Otherwise=0	0	1	.90	.298
Method of planting	Transplanting only=1 Broadcasting only=0	0	1	.2331	.42343
Use of tractor hitched with a harrow for land preparation	Yes=1 No=0	0	1	.3006	.45915
Use of a combined harvester for harvesting	Combined harvester=1 manual=0	0	1	.1938	.39585

Source: Field Survey (2012)

4.4 Testing of hypothesis

Results of the various hypothesis tested are presented in Table 4.3. For the first hypothesis, the null hypothesis that the Cobb-Douglas is suitable for the data is rejected at 0.01 level of significance in favour of the translog model. The translog form of the model is therefore the best fit for the data.

Table 4.3: Results of hypothesis test

Null Hypothesis	Test Statistic(λ)	Critical value(λ^2)	Decision
$H_0: \beta_{ij}=0$	146***	30.6	Reject H_0
$H_0: \psi_1 = \psi_2 = \dots = \psi_5 = 0$	118***	15.1	Reject H_0
$H_0: \lambda = 0$	33.5***	9.5	Reject H_0
$H_0: \delta_1 = \delta_2 = \dots = \delta_{14} = 0$	474***	29.1	Reject H_0
$H_0: \delta_{14} = 0$	189.5***	6.6	Reject H_0

Source: field survey 2012, ***, corresponds to 0.01 significance level. The critical value for the third hypothesis was obtained from Table 1 of Kodde and Palm (1986).

The second hypothesis which states that production risk in inputs is absent from the production process is also rejected at 0.01 level of significance. Implying that the conventional inputs are jointly related to production risk. This means that there is the presence of risk in the production process. The third hypothesis which also specifies that technical inefficiency is absent from the model, is rejected at 0.001 level of significance. From table 4.4 it is observed that the estimated lambda is 2.0 and it is significantly greater than zero. This implies that variation in the observed output from the frontier

output is due to technical inefficiency and random noise but the variation in output explained by technical inefficiency is relatively larger than the deviations in output from pure noise component of the composed error term. This makes the stochastic frontier model a better model than the deterministic frontier.

The fourth hypothesis which specifies that the exogenous factors and the conventional input factors do not jointly explain technical inefficiency is rejected at 0.01. This means that the variations in technical efficiencies are explained by the combined effect of the exogenous variables even though some variables are not significant.

The fifth hypothesis which states that there is no regional effect on efficiency is rejected at 0.01. This implies that the regional location of an irrigated rice farm has an effect on its efficiency.

The diagnostic statistics

The estimated sigma square (σ_s^2) parameter (0.14) and lambda ($\lambda = \sigma_u / \sigma_v$) parameter (2.0) in the stochastic frontier production function is significantly different from zero and this indicates a good fit of the model and the correctness of the specified distributional assumptions. A lambda value greater than 0 also implies that the variation in the observed output from the frontier output is due to technical inefficiency and random noise. However the variation in output explained by technical inefficiency is relatively larger than the deviations in output from the pure noise component of the composed error term. Gamma (γ) is also a measure of the level of the inefficiency in the variance parameter and it is estimated as (0.8) and is significant at 1 percent indicating that 80 percent of the total variations in rice output are due to technical inefficiencies in the study area.

Maximum likelihood estimates are presented in table 4.4 but discussion of parameters are based on output elasticities (table 4.5)

Table 4.4 Maximum likelihood estimates of the Translog Mean Output Function

Variable	Parameters	Estimates	Standard Error	P>[z]
Constant	α_0	-1.646845 ***	0.2608588	0.000
Ln Labour	α_1	-0.3891278 **	0.1600473	0.015
Ln fertilizer	α_2	0.0094702	0.1632488	0.954
Ln Seed	α_3	0.8553056 ***	0.1111963	0.000
Ln Othercost	α_4	0.4900135 ***	0.1325918	0.000
Ln Mechanization cost	α_5	0.2182943 *	0.1202014	0.068
Ln Labour ²	α_6	-0.1964328***	0.0562049	0.000
Ln fertilizer ²	α_7	-0.0367301	0.0353738	0.302
Ln Seed ²	α_8	-0.1953384***	0.0241856	0.000
Ln Othercost ²	α_9	0.0338795	0.0220903	0.125
Ln mechanization2	α_{10}	-0.0017788	0.025485	0.947
Ln Labour× Ln fertilizer	α_{11}	0.0796165 **	0.0328011	0.015
Ln Labour × Ln Seed	α_{12}	0.0789194 **	0.0340541	0.020
Ln Labour× Ln Othercost	α_{13}	-0.0024077	0.0259762	0.925
Ln Labour× Ln mechanization	α_{14}	0.0011405	0.0242753	0.961
Ln fertilizer× Ln Seed	α_{15}	0.0106942	0.0337187	0.751
Ln fertilizer× Ln Other cost	α_{16}	0.0253606	0.025435	0.320
Ln fertilizer× Ln mechanization	α_{17}	0.0624108 ***	0.0226302	0.006
Ln Seed× Ln Other cost	α_{18}	-0.1058527***	0.0281982	0.000
Ln Seed× Ln Mechanization	α_{19}	-0.0401166	0.0248262	0.105
Ln Other cost× Ln Mechanization	α_{20}	-0.0042099	0.0204996	0.838
Variance Parameters				
		Sigma-squared(u)	0.3301	0.018
		Sigma-squared(v)	0.1638	0.009
		Lambda ($\lambda = \sigma_u / \sigma_v$)	2.01	0.026
		sigma2	0.1358	0.009
		Gamma($\gamma = \lambda^2 / (1 + \lambda^2)$)	0.8	

*, **, *** corresponds to 0.1, 0.05 and 0.01 significance levels respectively

4.5 Elasticity of production and returns to scale

The concept of elasticity can be applied to the production function so as to determine the stage of production in which the rice farmers are operating. The elasticities of rice output with respect to the various inputs used as a measure of the resource productivity of the rice farmers. The output elasticities show the degree of responsiveness of rice output to changes in the various input variables. A summation of the partial elasticities of the various input variables with respect to output is a measure of the return to scale of the rice farms. Table 4.5 shows the result of the summation of the individual elasticities.

Table 4.5 Elasticity of production and returns to scale

Variables	Elasticity
Labour	-0.389**
Fertilizer	0.009
Seed	0.855***
Other cost	0.490 ***
Mechanization cost	0.218*
RTS	1.18

Source: Author's computation from field survey, 2012

*, **, *** corresponds to 0.1, 0.05 and 0.01 significance levels respectively

The study finds that all the output elasticities are all significant with the exception of fertilizer. However, even though labour was significant, it had a negative sign, meaning that as the variable is increased output falls. The output elasticity for labour, fertilizer, seed and other cost and mechanization cost are -0.389 percent, 0.009 percent, 0.855 percent, 0.4900 percent and 0.218 percent respectively. A percent increase in labour

employed per hectare decreases yield by 0.389 percent *ceteris paribus*. This indicates that farmers are currently operating in the third stage of production with respect to labour use. More labour per hectare is currently being employed than is needed. This may be due to the fact that farm labour is relatively cheap in the study area and farm activities are usually carried out in groups. Any farmer that needs assistance calls on other farmer friends for help and the cycle continues for the entire group. This system results in more labour being employed than is necessary. This finding is consistent with the study done by Ologbon et al. (2012) on adoption of 'Ofada' rice variety and technical efficiency of rice-based production systems in Ogun State, Nigeria. The maximum likelihood estimate for both hired and family labour was negatively related to output. The study by Rahman et al. (2012) on a stochastic frontier approach to model technical efficiency of rice farmers in Bangladesh: An Empirical Analysis also recorded a negative coefficient for labour for all the farm sizes.

Findings from this study indicate that a one percent increase in quantity of fertilizer applied per hectare will result in an increase in output by 0.009 percent. This implies that the usage of fertilizer positively increases yield, however this relationship is not strong. This result is also consistent with the study by Ahmadu and Alufohai (2012) on the estimation of technical efficiency of irrigated rice farmers in Niger state, Nigeria. Fertilizer was found to be positive but not significant. They attributed its insignificance to low quantities being used for production. A percent increase in the quantity of seed used per hectare results in output increasing by 0.855 percent. This indicates the optimum quantity of seed which can be used has not yet been reached. Increasing seed usage in the

study area will increase yield. A subsequent percent increase in other cost will result in output increasing by 0.4900 percent. This implies that more money spent on irrigation, agrochemicals, depreciation and other services go a long way to ensure an increase in yield. Rice is considered as a semi aquatic plant and hence thrives well in well watered soils. Water use and moisture stress effects vary at different growth stages of rice. Sufficient moisture supply is more critical in certain growth stages. Moisture stress reduces crop yield most when it occurs during the critical growth stages. The peak water demand of rice is between maximum tillering and the grain filling stage. In the study area agrochemicals in the form of selective herbicides such as Orizo plus etc. were used to control weeds in an attempt to allow the grains to grow devoid of competition for nutrients. Insecticides e.g. Pawa were also used to combat insect infestation which would lead to poorer yields. The employment of other services like cutting, threshing and milling also increases output because they help to determine the effectiveness of the harvesting process and the quantity and quality of the harvested output.

A percent increase in mechanization cost increases yield by 0.218. This highlights the importance of mechanization in the realizing of rice output. The use of farm machinery in the production process means that certain farm activities like land preparation, tillage and harvesting can be done more efficiently and hence result in the observance of a higher yield. This result is consistent with the study done by Bäckman et al. on determinants of technical efficiency of rice farms in north-central and north-western regions in Bangladesh. It also tried to capture mechanization in a variable they introduced as tractor and bullock. This variable showed a positive relationship to mean output (0.631). The

study on a stochastic frontier approach to model technical efficiency of rice farmers in Bangladesh: An Empirical Analysis by Rahman et al. (2012) also tried to capture mechanization in the form of a variable it named ploughing cost in the mean output function. This coefficient however was positive for only small farm size (0.0159). It was negative for the large, medium and marginal farm sizes (-0.0411, -0.0064, -0.0019 respectively). This study shows that output has the highest responsiveness to seed, followed by other cost, mechanization cost, labour and finally fertilizer. The prior assumption was that output is more responsive to seed than labour. The result of this study confirms this assumption.

The returns to scale coefficient is also called the function coefficient or total output elasticity. If all the factors are varied by the same proportion in the long-run, the function coefficient indicates the percentage by which output will be increased (Kibaara, 2005). For this study it is estimated at 1.18. This value is greater than one and hence production in the study area is characterized as increasing returns to scale. Farmers in the study area can still increase all factor inputs by one percent in the long run. This will result in output increasing by (1.18) more than the proportionate increase in the input factors.

4.6 Estimates of marginal output risk

Output variability in the production process has been explained by the input factors which reveal information for production risk management. Some of the inputs are risk reducing while others are risk increasing and this provides vital information to stabilize rice output. Estimates for the marginal input risk is presented in Table 4.6. labour, seed,

and other cost increase output variability, although the effect of seed and other cost is not strong. The result for labour being risk increasing is consistent with the work done by Villano and Fleming (2006) on technical inefficiency and production risk in rice farming: Evidence from Central Luzon Philippines. In this work labour was also classified as a risk increasing input. Fertilizer use and mechanization reduces output variability. This implies that the effective use of fertilizer and the proper management of mechanization can be used to reduce output variance. A risk averse farmer will therefore employ less of labour, seed and other cost due to the ability of these inputs to cause high fluctuations in yield. He may go ahead and use more of fertilizer and adopt better mechanization practices in order to reduce output. The result of seed as a risk increasing input is consistent with the work done by Picadzo-Tadeores and Wall (2003). The effect of an input however should not be tied prior to output variance but rather it should be an empirical issue (Just and Pope, 1978).

Table 4.6 Maximum Likelihood Estimates of the Linear Production Risk function

Variable	Parameter	Estimate	Standard Error	P>[z]
Constant	Ψ_0	-4.114***	0.185356	0.000
Labour	Ψ_1	1.200***	0.1260875	0.000
fertilizer	Ψ_2	-0.824***	0.1409654	0.000
Seed	Ψ_3	0.034	0.1465299	0.825
Other cost	Ψ_4	0.102	0.106494	0.342
Mechanization cost	Ψ_5	-0.252**	0.1014729	0.013

Source: field survey, 2012

*, **, *** corresponds to 0.1, 0.05 and 0.01 significance levels respectively

4.7 Inefficiency Model Estimates

With regards to efficiency differentials among the sampled rice farmers across the 2 locations, the estimates of technical inefficiency model provides some important insights. The estimates of the parameters for the determinants of inefficiency are presented in Table 4.7.

Table 4.7 Stochastic Frontier Estimation of farm level technical inefficiency factors

Variable	Parameter	Estimate	Standard Error	P>[z]
Constant	(Z ₀)	-2.240***	0.608	0.000
Age	(Z _{1i})	0.003	0.009	0.767
Years of farming	(Z _{6i})	0.025	0.017	0.140
Credit Access	(Z _{3i})	0.451**	0.181	0.013
Education	(Z _{2i})	0.248**	0.104	0.017
Gender	(Z _{5i})	-0.152	0.176	0.393
Extension visits	(Z _{4i})	0.222	0.286	0.437
Landownership	(Z _{7i})	-0.171	0.169	0.314
Family Size	(Z _{8i})	-0.010	0.037	0.785
Member of a FBO	(Z _{9i})	-0.921***	0.211	0.000
Main occupation	(Z _{10i})	-0.395	0.263	0.133
Method of planting	(Z _{11i})	-1.109***	0.236	0.000
Method of land preparation	(Z _{12i})	-1.507***	0.329	0.000
Mode of harvesting	(Z _{13i})	-1.158***	0.318	0.000
Regional effect	(Z _{14i})	-2.740***	0.384	0.000

Source: field survey, 2012 *, **, *** corresponds to 0.1, 0.05 and 0.01 significance levels respectively

From the estimates, age has a positive effect on technical inefficiency, indicating that farmers who are older are less efficient (more inefficient). Subsequent analysis also reveals that older farmers who have greater number of years of experience in rice farming (yrs farming) are more inefficient although this relationship is not strong it buttresses the argument that many years in rice farming only infers to adhering to old methods of

production which may be technically less efficient. Coelli and Battese (1996) pointed out that the age of the farmer could have a positive or negative effect upon the size of the inefficiency effects. He concludes that older farmers are to have had more farming experience and hence less inefficiency. However, it is also possible that older farmers could be more traditional and conservative and therefore show less willingness to adopt new practices. Another school of thought also suggests that ageing farmers would be less energetic to work on farm. Hence, this will lower technical efficiency. Villano and Fleming (2006) argued that the influence of age on technical efficiency is relative to the empirical data being analysed. Age can only influence technical efficiency positively if the older farmers gain experience to know the best farm practices. On the other hand, age can influence technical efficiency negatively if the farmers are unwilling to take risk to adopt the best farm practices. However the finding in this study with respect to age is weak.

Farmers' access to credit as often claimed by development theory is to improve liquidity and enhance the use of inputs in production. The estimates obtained however for the study area indicates that the variable access to credit is significant but however positively related to technical inefficiency (increases inefficiency). This implies that the farmers in the study area source for credit but somehow it is not translated into production activities hence there is a diversion of credit to other non-farm activities.

Farmers that had attained a higher level of education were more inefficient (less efficient). This can be attributed to the fact that the highly educated farmers have a wide

array of income generating sources to choose from and hence tend to channel their energy into other income generating sources outside the farm sector thereby sacrificing both the human and material capital needed to increase efficiency. Empirical studies offer varied opinions about the effect of education on inefficiency. According to Battese and Coelli (1995) education is hypothesized to increase the farmers' ability to utilize existing technologies and attain higher efficiency levels. Owour and Shem (2009) however indicated that educational level is negatively correlated to technical efficiency of farmers. One possible explanation is that technical skills in agricultural activities, especially in developing countries are more influenced by "hands on" training in modern agricultural methods than just formal schooling. Another school of thought has it that technical inefficiency tends to increase after 5 years of schooling. This could probably be explained by the fact that high education attenuates the desire for farming and therefore, the farmer probably concentrates on salaried employment instead (Kibaara, 2005). Ultimately, this reduces labour availability for farm production thereby lowering efficiency.

The result of the coefficient of the gender variable indicates that, being a male rice producer reduces technical inefficiency than being a female. This result is in agreement with the findings of Kibaara (2005) that being a male farmer decreases technical inefficiency. This could be explained by the fact that men have greater access to credit, probably because of cultural prejudice, and hence men are closer to the production frontier. In addition, men are most likely to attend agricultural extension training seminars (Kibaara, 2005). The impact of this variable however is not strong.

Another important factor considered in this analysis was number of extension visits. According to Alhassan (2008), extension visits to farmers enable them to use recommended cultural practices in rice production to improve upon their efficiency. Extension agents are supposed to provide advisory services and training of the farmers to improve upon their efficiency. The result of this variable for the study area is not significant and also positively influences inefficiency. This implies that farmers' interactions with the extension agent do not result in enhancing efficiency. It is either because the extension agents themselves are not adequately trained and so the quality of information needed to increase efficiency is inadequate or the number of contacts the farmers have with these extension officers is too minimal to cause a change in efficiency levels. Owens et al. (2003) in analyzing the impact of extension services on agricultural production in Zimbabwe found that farmer's access to extension services increases the value of output by 15 percent Alemu et al. (2002) on the other hand had opposite results. Their results revealed that neither extension visits nor visits and trainings could bring about significant reductions in inefficiency levels. This they attributed to the fact that the development agents or extension agents remain at the edge, never reaching the farmer and that the training packages may not fit the agro ecological settings. He argued that it is not extension services in terms of visits that makes the difference but the appropriateness of the extension message or training.

The results also show that farmers who are operating on rented land are more inefficient (less efficient) than land owners although its impact is not strong. Empirical results on ownership of land on inefficiency are mixed. A positive relationship with efficiency is

consistent with the hypothesis that longer years of leasing motivate farmers to work harder to meet their contractual obligations (Helfand and Levine, 2004; Coelli et al., 2005). A negative relationship on the other hand is linked to the agency theory, reflecting monitoring problems and adverse incentives between the parties involved in diminishing business performance (Giannakas et al., 2003; Reddy, 2002).

From the results, family size significantly reduces technical inefficiency because larger household sizes tend to benefit from being able to use labour resources at the right time (Dhungana et al., 2004). A large family size would mean more family labour will be available for farming activities. This will result in a higher efficiency because of the availability of labour to carry out crop husbandry activities in a timelier manner. This variables impact for this study is however not strong.

The results further reveals that being a member of a farmer based organization reduces technical inefficiency. The farmer based organizations help to disseminate information on best farming practice among its members. They are also active when it comes to the procurement of inputs such as improved seeds and fertilizer. It also assists farmers in the access of credit facilities. Farmers who were engaged in rice farming as their main occupation were more efficient than farmers who had their main source of livelihood from other occupations. Farmers that have rice farming as their main source of income tend to invest more material and managerial resources into production and hence are more efficient. Its impact however is not strong.

Farmers that employed the transplanting method alone for the production year were more efficient (less inefficient) as compared to those who used other methods like the broadcasting method. The transplanting method of planting ensures that only viable plants are transferred to the farm (plants that are more likely to produce a yield) with the right spacing, so that each plant has an equal chance of survival. With the broadcasting method on the other hand, a lot of the seeds are wasted. More seeds may fall into one space and will have to compete for nutrients resulting in a relatively lower yield.

The results also show that, the farmers that used the power tiller for tillage during land preparation had a significantly lower inefficiency as compared to those that used a tractor and a harrow for tillage. This is because the harrow allows deep tillage of the soil which improves soil aeration and subsequently yield.

Farmers that employed the use of combined harvesters during harvesting were more efficient than those who did manual harvesting.

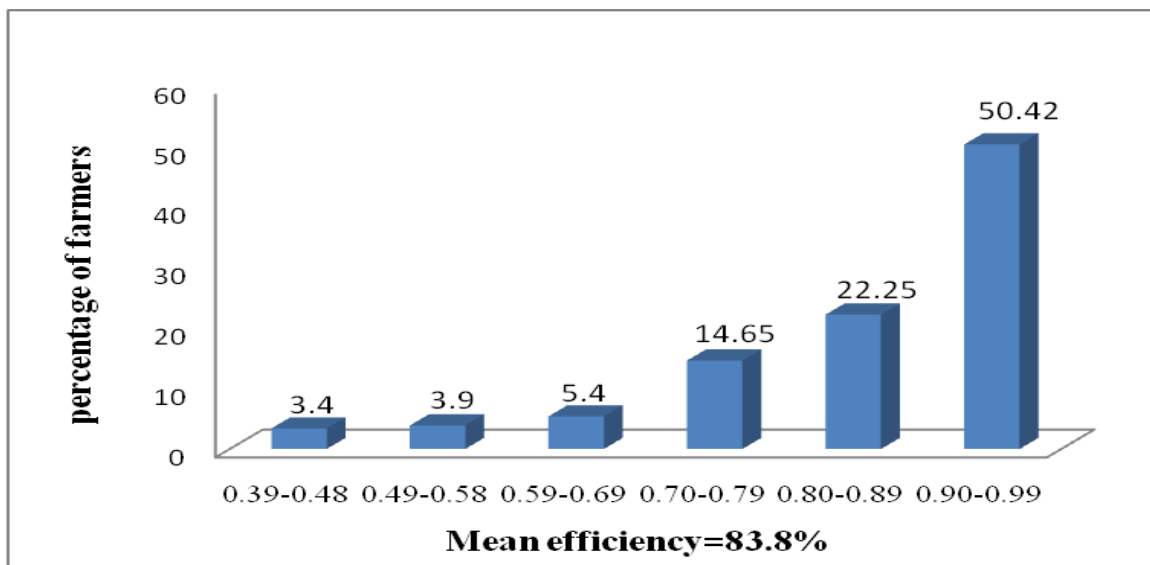
The farmers in Greater Accra Region are more efficient than farmers in the Volta Region.

4.8 Technical efficiency Estimates

The technical efficiency estimates range from 39 percent to 99 percent. About 50 percent (50.42 percent) of the farmers are operating in the technical efficiency range of 0.90 and 0.99 (Figure 4.1). The least technical efficiency range is between 0.39 and 0.48 and 3.4 percent of the farmers are lying within this range. The mean technical efficiency is approximately 84 percent. This implies that on the average the farmers are 16.2 percent

below the frontier output at the given technology. There is therefore the possibility of increasing the output of the rice farms in the study area by 16.2 percent on average in the short run by adopting the practices of the best farm. The use of best farm practice technology such as transplanting and proper mechanization can contribute effectively towards the achievement of the frontier output.

Figure 4.1 Distribution of technical efficiency using the SFP model



Source: field survey, 2012

This study's mean efficiency of 84 percent is consistent with the study done by Bäckman et al. (2011) on determinants of technical efficiency of rice farms in north-central and north-western regions in Bangladesh where the mean technical efficiency was estimated as 83 percent. It is also to some extent consistent with the work by Donkoh et al. (2013) on the technical efficiency of rice production at the Tono irrigation scheme in Northern Ghana where the mean efficiency was also estimated as 81 percent. In a related study on rice production in the Northern Ghana by Alhassan (2008) the lowest level of technical efficiency for irrigated rice farms was 12 percent, the highest was 88 percent and the

mean 53 percent. The efficiency scores also indicates that if the average rice farmer among the sampled rice farms is to attain the efficiency level of the most technically efficient rice farm, then that farmer will have to realize a 16.2 percent cost savings (i.e., 1-[83.8-99]). The most technically inefficient rice farmer will also have to realize a cost reduction of 61 percent (i.e., 1-[39-99]) in order to achieve the technical efficiency level of the most efficient rice farm.

4.9 Technical efficiency across the two regions

The farm-specific technical efficiency is segregated into two regions. The estimated technical efficiency score for rice farmers in the Greater Accra Region varies from 0.41 to 0.99 with an average score of 0.84. However that of the Volta region ranges from 0.39 to 0.99 with an average of 0.81. The technical efficiency estimates across regions is presented in Table 4.9 below

Table 4.8 Technical efficiency scores across districts

Technical efficiency intervals	Volta Region	Greater Accra Region	Total
0.39 - 0.48	12	0	12
0.49 - 0.58	11	3	14
0.59 - 0.69	10	9	19
0.70 - 0.79	34	18	52
0.80 - 0.89	21	58	79
0.90 - 0.99	3	176	179
Total	91	264	355
Mean	0.889	0.686	
Minimum	0.39	0.41	
Maximum	0.99	0.99	
Standard Deviation	0.15	0.13	

Source: Authors computation

4.10 Equality of Means

The null hypothesis which states that the mean technical efficiency for Greater Accra Region is the same as that of Volta region is rejected at 1 percent. This implies that there is a significant difference between the mean technical efficiencies of the two regions in favour of Greater Accra.

Table 4.9: Test of Equality of Means

Region	N	Mean	Mean difference	t	Sign (2-tailed)
Greater Accra	264	0.889	.203	t= 16.5008	0.0000***
Volta Region	91	0.686			

Source: Author's computation from survey data, 2012, *** represents 0.01 level of significance

Farmers in the Greater Accra Region are therefore more efficient than those in the Volta Region. Observations made on the field suggest that the difference in technical efficiency in both locations can be attributed to the differences in effective management and operations. The irrigated rice farmers in the Greater Accra region are both irrigation schemes are under the Irrigation development authority which has its headquarters in Accra. It is likely that the proximity of the Kpong irrigation project to the headquarters may facilitate the dissemination of relevant information on best farm practices which will increase the farms efficiency.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of major findings, conclusions and policy recommendations of the study.

5.2 Summary of Major Findings

This study adopts the stochastic frontier model with flexible risk properties to a sample of 356 rice farms in the Greater Accra and Volta regions in an attempt to properly understand the irrigated rice production process. A single stage maximization of the model using STATA 12 provides the estimates of the stochastic frontier model with flexible properties composed of the mean output, production risk and inefficiency models.

The findings show that the translog production function is the best fit for the model. The study also finds that production risk is jointly explained by seed, labour, fertilizer other cost and mechanization cost. Lamda is estimated to be 2.0 and this is significant from 0. It implies that the deviations in output as a result of technical inefficiency are more pronounced than the deviation in output as a result of the pure noise component in output. Output variability is also as a result of production risk which is present in the production process. The variation in the observed output from the frontier output is also due to technical inefficiency and the presence of production risk in the irrigated rice production process. The variations in technical efficiencies are also explained by the combined effect

of the exogenous variables even though some variables are not significant. There is also a regional effect on the efficiency levels observed. Irrigated rice farms in the Greater Accra Region are more efficient than irrigated rice farms in the Volta Region.

The results of the frontier mean output function indicates that estimated output elasticities of seed, fertilizer, other cost and mechanization cost are positive implying that an increase in any of these inputs has the potential to increase rice output. The elasticity of labour however is negative implying that an increase in labour will decrease output. The study finds that the production technology characterizing irrigated rice farms in the study area exhibits increasing returns to scale.

Labour, seed and other cost increase output risk. Whereas fertilizer and mechanization cost decreases output risk.

Irrigated rice farms in the study area are operating below the production frontier. The mean predicted technical efficiency while using the stochastic frontier function with flexible risk components is 83.8 percent. The mean technical efficiency estimate for this study if risk is not considered is 82 percent.

It is revealed that, educational level, credit access, being a member of a farmer based organization, method of planting, method of land preparation and mode of harvesting all affect technical efficiency. Farmers who were more educated were less efficient, farmers who had access to credit were also less efficient. Farmers who used the power tiller for tillage during land preparation were less efficient than those who used a tractor and a harrow for tillage during land preparation. On the other hand farmers who were members

of farmer based organizations were more efficient than those who were not. Farmers who employed the transplanting method only for the production year were also more efficient than those who employed the broadcasting method. Farmers who employed the use of a combined harvester during the harvesting process were more efficient than the farmers that did manual harvesting. The finding also shows that the impact of extension service on efficiency in the study area is not significant.

5.3 Conclusions

This study concludes that the translog form of the model is the best fit for the data. Production risk is jointly explained by labour, fertilizer, seed, other cost and mechanization cost. The deviations in output as a result of technical inefficiency are more pronounced than the deviation in output as a result of the pure noise component in output (lambda value of 2.0). The combined effects of farm specific factors are able to explain variation in technical efficiency even though some individual variables are not significant. Irrigated rice farms in the study area are operating below the production frontier and this is due to the presence of both production risk and technical inefficiencies in the production process of irrigated rice farms in the Greater Accra and Volta region of Ghana.

The conventional input factors labour, fertilizer, seed, other cost and mechanization cost are important in the irrigated rice production process. Seed, fertilizer and other cost increase mean output of rice. The input variable labour reduces mean output. The

production technology characterizing irrigated rice farms in the study area exhibits increasing returns to scale (1.18).

Labour, seed and other cost are risk increasing inputs. Fertilizer and mechanization cost are risk reducing inputs and hence can be used to mitigate the effect of production risk.

The study concludes that not accounting for production risk in technical efficiency estimations results in biased technical efficiency estimates. The mean technical efficiency for the sampled farms is 83.8 percent. The existing technical efficiency estimate presents the opportunity to increase rice output by 16.2 percent without employing additional resources. Highly educated farmers are less efficient. Farmers that have access to credit in the study area are less efficient. Irrigated rice farmers in the Greater Accra region are more efficient than those in the Volta Region. The farmer based organizations in the study area are the Osudoku agricultural cooperative society and Afife rice and vegetable irrigation cooperative. Being a member of these farmer based organization increases farmer efficiency. The use of the power tiller for tillage during land preparation reduces efficiency as compared to the use of a tractor hitched with a harrow for tillage. The transplanting method of planting enhances efficiency. Farmers who employ the use of combined harvesters during the harvesting process are more efficient than the farmers that do manual harvesting. The extension service in the study area does not strongly affect farmer efficiency. Farmers in the Greater Accra Region are more efficient than farmers in the Volta Region

5.4 Policy Recommendations

Based on the findings of this study, the following policy recommendations are made for policy action to be taken in order to help boost rice output, eliminate technical inefficiencies and mitigate the effect of risk in the production process.

The study recommends that irrigated rice farmers in the study area should increase the use of inputs such as seed, fertilizer, other cost and mechanization cost since increasing these inputs has the potential to increase rice output. The increase in the usage of inputs can be made possible if the Ministry of food and Agriculture ensures that inputs are readily available, affordable and accessible to farmers. The employment of the input variable labour must be reduced since it is evident that the farmers are operating in the third stage of production with respect to labour.

Since fertilizer and mechanization are risk reducing inputs, the Ghana irrigation development authority must encourage these irrigated rice farmers to properly manage fertilizer and mechanization properly as a way to mitigate the effect of yield fluctuations. Since the farmers that employed the transplanting only method were more efficient than those who employed the broadcasting method. The Ghana irrigation development authority must encourage irrigated rice farmers to use the transplanting method of planting instead of the broadcasting method. The results also revealed that being a member of a farmer based organization is a key factor in enhancing farmer efficiency. The farmer based organizations often serve as production information dissemination sources and also input procurement facilitators. The study therefore recommends that the

Ministry of food and Agriculture, the Ghana irrigation development authority and other stakeholders should encourage irrigated rice farmers to form associations or join the already existing ones such as the Osudoku Agricultural cooperative society and the Afife rice and vegetable irrigation cooperative. Efforts must be made by the Ministry to strengthen them so that they can intern help the farmers to boost their production.

Government institutions and other financial institutions that give credit to farmers should give the credit in the form of input supply or hiring machinery services like tractor services to ensure that credit is not being diverted to other non-farm operations.

The Ministry of food and agriculture must repackage the extension and advisory services to farmers so that its impact can be better felt and translated into higher efficiency of the rice farms. The Ministry must also ensure that at every point in time the extension agents themselves are abreast with current best farm practices. This will affect the quality of information relayed to farmers and hopefully will be translated into less inefficiencies in the production system. In repackaging the extension services, provision must be made to cater for the different educational groups. This is because the level of education ultimately affects the dissemination method used and its effectiveness.

References

- Abedullah, S. K. & Mushtaq, K. (2007). Analysis of Technical Efficiency of Rice Production In Punjab (Pakistan): Implications for Future Investment Strategies. *Pakistan Economic Social Review*, 45: 231-244.
- Ahmadu, J. & Alufohai, G. O. (2012). Estimation of Technical Efficiency of Irrigated Rice Farmers in Niger State. *American-Eurasian Journal of Agriculture & Environmental Sciences*, 12 (12): 1610-1616.
- Aigner, D. J. & Chu, S. F. (1968). Estimating the Industry Production Function. *American Economic Review*, 58 (4) 826 – 839.
- Aigner, D. J., Lovell. A. K. & Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics*, 6, 21-37.
- Ajibefun, I. A. (2008). An Evaluation of Parametric and Non-Parametric Methods of Technical Efficiency Measurement: Application to small scale food crop production in Nigeria. *Journal of Agriculture & Social Sciences*, ISSN Print: 1813–2235.
- Alemu, B.A., Nuppenu, E. A. & Boland, H. (2002). Technical Efficiency of Farming Systems across Agro-Ecological Zones in Ethiopia: An application of stochastic frontier analysis.
- Al-hassan S. (2008). *Technical Efficiency of Rice Farmers in Northern Ghana*. Final Report Presented At African Economic Research Consortium, Nairobi. Research paper 178.
- Antle, J.M. (1983). Testing the Stochastic Structure of Production: A flexible moment based approach. *Journal of Business and Economic Statistics*, 1(3): 192-201.
- Asare-Osei, Y.B. (2010). *Mapping of Poverty Reduction Strategy Papers (PRSPS), Sector Strategy and Policies Related to Rice Development in Ghana*. Coalition for African rice development (CARD).
- Asche, F., & Tveteras, R. (1999). Modeling Production Risk with a Two-Step Procedure. *Journal of Agricultural and Resource Economics* 24(2):424-439.
- Bäckman, S., Islam, K. M. Z. & Sumelius, J. (2011). Determinants of Technical Efficiency of Rice Farms in North-Central and North-Western Regions in Bangladesh. *The Journal of Developing Areas*, 45(1), 73–94.

- Badawi, T. A. (2004). *Rice-based Production Systems for Food Security and Poverty Alleviation in the Near East and North Africa: New Challenges and Technological Opportunities*. Fao Rice Conference 04/CRS.25 Rome.
- Balasubramanian, V., Sie, M., Hijmans R.J. & Otsuka K. (2007). Increasing Rice Production in Sub-Saharan Africa: Challenges and opportunities. *Advances in Agronomy*, Vol. 94.
- Battese, G. (1997). A note on the Estimation of Cobb-Douglas Production Functions when some explanatory variables have zero values. *Journal of Agricultural Economics* 48(2), 250-252.
- Battese, G. E. (1992). Frontier Production Functions and Technical Efficiency: A survey of empirical applications in agricultural economics. *Agricultural Economics*, 7, 185-208.
- Battese, G. E. & Coelli T. J. (1995). A model for Technical Efficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics* 20,325-332.
- Battese, G. E., Rambaldi, A. N. & Wan, G. H. (1997). A Stochastic Frontier Production Function with Flexible Risk Properties. *Journal of Productivity Analysis*. 8 269.280.
- Battese, G.E. & Coelli, T.J. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics* 20 325-332.
- Battese, G.E. & Coelli, T.J (1998). Prediction of firm level technical efficiency with a generalized frontier production functions and panel data. *Journal of Econometrics* Vol. 38(1988) 387-399.
- Battese,G.E. & Corra, G.S. (1977). Estimation of a Production Frontier Model: With application to the Pastoral Zone of Eastern Australia, *Australian Journal of Agricultural Economics*, vol. 21:pp169 179.
- Binswanger, H. P. (1980). Attitudes toward Risk: Experimental measurement in rural India. *American Journal of Agricultural Economics*, 62: 395-407.
- Binswanger, H.P. (1981). Attitudes toward risk: Theoretical implications of an experiment in rural India. *The Economic Journal*, 91: 867-890.
- Boadu, V. A. (2011). *Rice Price Trends in Ghana (2006-2011)*. METSS-Ghana Research and Issue Paper Series No. 02-2012 - June 2012.

- Bokusheva, R. & Hockmann, H. (2006). Production risk and technical inefficiency in Russian agriculture. *European Review of Agricultural Economics* 33:93-118 .
- Charnes, A. ,Cooper, W. W. & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*. 2 (4) 429 - 444.
- Coelli, T. J. & Battese G. E. (1996). Identification of factors which influence the technical inefficiency of Indian farmers. *Australian Journal of Agricultural Economics* 40,103-128.
- Coelli, T. J., Rao, D. S. P., O'Donnell, C. J. & Battese G. E. (2005). *An Introduction to Efficiency and Productivity Analysis*, 2nd Edition, Springer Publishers, U.S.A.
- Coelli, T. & Battese, G. (1996). Identification of factors which influence the technical inefficiency of Indian farmers. *Australian Journal of Agricultural Economics*, Vol.40 No: 2.pp103-128.
- Coelli, T.J., Rao, D.S.P., O'Donnell, C.J. & Battese, G.E. (2005). *An Introduction to Efficiency and Productivity Analysis* , 2nd Edition, Springer.
- Dhungana, B.R., Nuthall, P.L. & Nertea, G.V. (2004). Measuring the economic inefficiency of Nepalese Rice Farmers using data envelopment analysis. *Australian Journal of Agricultural and Resource Economics*, 48:347-369.
- Donkoh, S. A., Ayambila, S. & Abdulai, S. (2013). Technical Efficiency of Rice Production at the Tono Irrigation Scheme in Northern Ghana, *American Journal of Experimental Agriculture* 3(1): 25-42, 2013.
- Fagade, S.O. 2000. *Yield gaps and productivity decline in rice production in Nigeria. In Proceedings of the Expert Consultation on Yield Gap and Productivity Decline in Rice*, 5-7 Sept. 2000, FAO, Rome
- Falusi, A.O. 1997. *Agricultural development and food production in Nigeria: problems and prospects*. In: Shaib, B., Adedipe, N.O., Aliyu, M. & Jir, M. eds. *Integrated agricultural production in Nigeria: Strategies and mechanisms*. NAR Monograph No. 5. p. 151-170.
- Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*, Series A, Vol.120, No. 3.
- Frank A. & Ragnar T. Modeling Production Risk with a Two-Step Procedure. *Journal of Agricultural and Resource Economics*, 24(2):424-439.
- Fufa, B. & Hassan, R. M. (2003). Stochastic Maize Production Technology and Production Risk Analysis in Dadar District, East Ethiopia. *Agrekon*, 42 (2), 116-128.

- Garcia del Hoyo J. J., Castilla Espino, D. & Jimenez Toribio, R. (2004). Determination of technical efficiency of fisheries by stochastic frontier models: A case on the Gulf of Cadiz (Spain). *ICES Journal of Marine Science*, 61, 416-421.
- Ghana Statistical Service. (2002). *2000 Population and housing census: Summary report of final results*. Accra: Ghana Statistical Service.
- Giannakas, K., Tran, K.C. & Zouvelekas, T. V. (2003). Predicting Technical Efficiency in Stochastic Production Frontier Model in the Presence of Misspecification: A Monte- Carlo Analysis. *Applied Economics*, 352153-161.
- Government of Ghana. (2009). *National Rice Development Strategy (NRDS)*: Ministry Of Food and Agriculture.
- Government of Ghana. (2007). *Food and Agriculture Sector Development Policy (FASDEP11)*: Ministry of Food and Agriculture.
- Government of Ghana. (2009). *Medium Term Agriculture Sector Investment Plan (METASIP)*: Ministry of Food And Agriculture. 2009–2015.
- Helfand, S. & Levine, E. S. (2004). Farm Size and Determinants of Productive Efficiency in Brazilian Centre-West. *Agricultural Economics*, 31: 241-249.
- Huang, C. J. & Liu, J. T. (1994). A Non-neutral Stochastic Frontier Production Function. *Journal of Productivity Analysis* 5,171-180.
- Japan International Cooperation Agency (JICA). (2007). *The Study on the Promotion of Domestic Rice in the Republic of Ghana*.
- Just, R.E. & Pope, R.D. (1978). Stochastic Representation of Production Functions and Econometric Implications. *Journal of Econometrics* Vol 7.
- Khai, H. V. & Yabe, M. (2011). Technical efficiency analysis of rice production in Vietnam. *Journal of International Society for Southeast Asian Agricultural Sciences* Vol.17,No.1:135-147.
- Kibaara, B. W. (2005). *Technical Efficiency in Kenyan's Maize Production: An application of the stochastic frontier approach*. Department of Agricultural and Resource Economics, MSc. Thesis, Colorado State University.
- Kodde, D. A. & Palm, A. C. (1986). *Wald Criteria for jointly testing equality and inequality restrictions*. *Econometrica*, 54, 1243-1248.

- Kumbhakar, S.C. (2002). Specification and estimation of production risk, risk preferences and technical efficiency. *American Journal of Agricultural Economics* 84, 8-22.
- Kumbhakar, S. C. & Lovell, C. A. K. (2000). *Stochastic Frontier Analysis*. Cambridge University Press.
- Love, H.A. & Buccola, S.T. (1991). Joint Risk Preference-Technology Estimation with a Primal System. *American Journal of Agricultural Economics* 73, 765-774.
- Meeusen, W. & Van den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed errors. *International Economic Review* 18: 435-444.
- Millennium Development Authority (MiDA) (2010). *Investment opportunity in Ghana, maize, soya and rice production and processing*.
- Mobil, J. & V.K. Okran (1985). *Trends in the production and consumption of rice in Ghana*. Accra, Ghana.
- Multi-Agency Partnerships (MAPS) (2003). *Technical Change In West African Agriculture: Rice production and livelihood in Ghana*.
- Namara, R. E., Horowitz, L., Nyamadi, B. & Barry, B. (2011). *Irrigation Development in Ghana : Past experiences, emerging opportunities, and future directions*.
- Ogundari, K. & Akinbogun, O.O. (2010). Modelling technical efficiency with production risk. A study of fish farms in Nigeria. *Marine Resource Economics* ,vol 25.
- Ologbon, O.A.C., Ikheloa, E.E. & Akereke, E.O. (2012). Adoption of “Ofada” Rice Variety and Technical Efficiency of Rice-Based Production Systems in Ogun State. *World Journal of Agricultural Sciences* 8 (6): 624-631, 2012 ISSN 1817-3047.
- Onumah, E. E. & Acquah, H. D. (2010). Frontier Analysis of Aquaculture Farms in the Southern Sector of Ghana. *World Applied Sciences Journal* 9(7):826-835.
- Owens, T., Hoddinott, J. & Kinsey, B. (2003). The Impact of Agricultural Extension on Farm Production in Resettlement Areas of Zimbabwe. *Economic Development and Cultural Change*, 51.
- Owuor, G. & Shem, O. A. (2009). *What Are the Key Constraints in Technical Efficiency of Smallholder Farmers in Africa: Empirical Evidence from Kenya*. A Paper Presented at 111 EAAE-IAAE Seminar ‘Small Farms: decline or persistence’ University of Kent, 26-27th June.

- Picazo-Tadeo, A. J. & Wall A. (2011). Production risk, risk aversion and the determination of risk attitudes among Spanish rice producers. *Agricultural Economics Journal*.1-14.
- Pope, R. D. & R. A. Kramer (1979). Production Uncertainty and Factor Demands for the Competitive Firm. *Southern Economic Journal*, 46: 489-501.
- Preferences & Technical Efficiency: *Evidence from Rain fed Lowland Rice Farms in the Philippines*. Working Paper Series in Agricultural and Resource Economics, paper No. 2005-1, University of New England.
- Quaye W., P. Greenhalgh, J. T. Manful & Hammond, L. (2000). *Rice Parboiling in Ghana, A Socio-Economic Survey*. NRI Report No. 5577, Project R7543, Food Research Institute, Accra. (unpublished).
- Rahman, K.M.M., Mia, M.I.A. & Bhuiyan, M.K.J. (2012).A stochastic frontier approach to model Technical Efficiency of Rice Farmers in Bangladesh: An empirical analysis. *The Agriculturists* 10(2):9-19 ISSN.1729-5211.
- Reddy, M. (2002).Implications of Tenancy Status on Productivity and Efficiency: Evidence from Fiji. *Sri Lankan Journal of Agricultural Economics*, 4: 19-37.
- Reifschneider, D. & Stevenson, R., (1991). Systematic departures from the frontier: a framework for the analysis of firm efficiency. *International Economic Review* 32,715-723.
- Sadoulet, E. & A. de Janvry (1995). *Quantitative Development Policy Analysis. Baltimore and London*. The Johns Hopkins University Press: 140-149.
- Tewodros, K.A. (2001). Farm household technical efficiency: *A stochastic frontier analysis. A study of rice in Mardi Watershed in Western Development Region of Nepal*. MSc. Thesis. Department of Economics and Social Sciences, Agricultural University of Norway.
- Villano R.A. & Fleming E. (2006) .Technical inefficiency and production risk in rice farming: Evidence from the central Luzon Philippines. *Asian Economic Journal*. Vol. 20 No.129-46.
- Villano R.A., O'Donell, C.J. & Battese, G.E. (2005). *An investigation of Production Risk, Risk Preferences and Technical efficiency: Evidence from rain fed lowland rice farms in the Philippines*. Working Paper series in Agricultural and Resource Economics, ISSN 1442 1909

- Wan, G.H. & Battese, G.E. (1992). *A stochastic Frontier Production function incorporating flexible risk properties*. Paper presented at the Australasian Meeting of the Econometric Society, Monash University, Melbourne, 6-8 July 1992.
- Wanda, O. (2009). *Production risk and input use in Banana Production in Uganda* MSc. Thesis, Makerere University.
- West Africa Rice Development Association, (WARDA) (2011). *Boosting Africa's rice sector: A research for development strategy 2011-2020*. Cotonou, Benin.
- West Africa Rice Development Association, (WARDA) (2007). *Africa Rice Trends: Overview of recent development in Sub-Saharan Africa rice sector*. Africa Rice Center Brief. Cotonou, Benin.
- Wik, M., Kebede, T. A., Bergland O. & Holden S. T. (2004). On the Measurement of Risk Aversion from Experimental data. *Applied Economics*, 36: 2443-2451.
- Yamane, T. (1967). *Elementary Sampling Theory*. Englewood Cliffs, New Jersey, Prentice-Hall
- Owusu, P. A. & Nyantakyi E. K. (2013). Assessing Performance of Irrigation of Rice in Ghana. *Journal of Science and Technology* Vol. 3, ISSN 2225-7217.

APPENDIX**DEPARTMENT OF AGRICULTURAL ECONOMICS AND
AGRIBUSINESS****UNIVERSITY OF GHANA, LEGON****PRODUCTION RISK AND TECHNICAL EFFICIENCY OF RICE
FARMS**

Questionnaire

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 number:

*Disclaimer: Any information provided by respondents is specifically for the purpose of
Data analysis in respect of the above mentioned topic*

Name of respondent.....
 Region.....
 Telephone number.....
 Location/District.....
 Name of enumerator.....
 Date.....

Socioeconomic characteristics of the respondent

1. Gender 1= male () 2= female ()
2. Age.....
3. Level of educational Attainment
 - 0= No schooling () 1= primary () 2=Middle school/ JSS () 3=SSS ()
 - 4=Vocational () 5= polytechnic level () 6=University (bachelor) level ()
 - 7=University (Graduate or Above) level ()
4. Marital Status 0= Single () 1=married () 2=divorced () 3=widowed ()
5. Ethnicity.....
6. Main occupation 1= rice farming () 0=other ()
- 6.a If other Specify.....
7. Family Size (aside the respondent).....
8. Number greater than 18 years and number less than 18 years

Number of adults >18yrs		Number of Children <18yrs	
Males	Females	Males	Females

9. Member of farmer based organization. 1= yes () 0=No ()

If yes Specify.....

If No why.....

10. Extent of mechanization

- a. 1=Simple farm tools () 2= tractor () 3=Plough () 4=Harrow ()
5=power tiller () 6= combined harvester 7=other, specify.....

11. Cost of mechanization for 2011 minor season.....

12. Cost of mechanization for 2012 major season.....

13. Access to credit facility for rice production in 2011 minor season

- a. 1=yes () 0=no ()
b. If Yes from what source.....
c. what was the interest rate charged.....

14. Access to credit facility for rice production in 2012 major season

- a. 1=yes () 0=no ()
b. If Yes from what source.....
c. what was the interest rate charged.....

15. Did you have any contact with any extension agent in the 2011/2012 cropping year.

- a. 1=yes () 0=no ()
b. If yes how many times.....

16. How many years has the farmer been engaged in farming of rice.....

A. Crop Production

17. Land ownership

- a. 1= owned () 2=rented/ leased ()

18. Total land area used for rice production in 2012 major season

.....

19. Total land area used for rice production in 2011 minor season.....

20. How **many times** is rice cultivated in a year on your farm and in which **months**

.....

21. Please indicate the type of seed used in planting during the 2011 minor season and the 2012 major season

2012 Major 1=improved () 2=traditional ()

name.....

....

From what source.....

2011 Minor 1=improved () 2=traditional ()

name.....

from what source.....

22. Please indicate the quantity of seed used for 2011/2012 crop year. Please indicate the type of bag 25kg etc.

Quantity of Seed(kilogram)			
Major Season(Quantity)	Price per bag (GHC)	Minor Season(Quantity)	Price per bag (GHC)

23. Did you apply any fertilizer (inorganic) for the 2011/2012 crop year 1=yes ()
2=No ()

a. Specific type.....

24. If yes please indicate the quantity of the inorganic fertilizer used for the 2011/2012 crop year

	Quantity (number of bags)		
Major Season	Price/bag	Minor Season	Price/bag

25. What about organic fertilizer. 1=Yes 0=No

26. If yes, which type and quantity

a. Type.....

b. Quantity.....

27. Is your rice irrigated or rain fed

a.

28. What is the cost of irrigation

2012 Major season.....

2011 Minor season.....

29. Kindly provide the number, year of purchase and current price of the following capital items

Item	Quantity	Year of purchase	Current price(GHC)	Lifespan in years
Hoe				
Cutlass				
Knapsack sprayer				
Tractor				
Other, specify.....				

30. Type of cultivation method for 2012 major season 1=transplanting () 2=
broadcasting() 3= other, specify.....
31. Type of cultivation method for 2011 minor season 1=transplanting () 2=
broadcasting() 3= other, specify.....

23. Farm labour activity and requirements during 2012 major crop Season (A=Adult, C=Children)

Farm Activity	Family Labour								Hired Labour											
	Male				Female				Male				Female							
	Num ber	Num ber of days	Wa ge/ day	Total wage paid	Nu mbe r	Nu mbe r of days	Wag e/da y	Tota l wag e paid	Nu mbe r	Num ber of Days	Wag e/da y	Tota l wag e paid	Qua ntity	Numb er of days	Wag e/da y	Total wage paid				
A	C	A	C		A	C	A	C		A	C	A	C		A	C	A	C		
Nursery bed preparation																				
Land preparation																				
Primary tillage																				
2 nd tillage																				
Flooding																				
Transplanting																				
Weedicide application																				
Insecticide application																				
Fertilizer application																				
Scaring																				
Harvesting																				
Drying																				
Bagging																				
Milling																				
Transportation to storage																				

24. Farm labour activity and requirements during 2011 minor crop Season (A=Adult, C=Children)

Farm Activity	Family Labour										Hired Labour								
	Male				Female						Male				Female				
	Num ber	Num ber of days	Wa ge/ day	Total wage paid	Nu mbe r	Nu mbe r of days	Wag e/ da y	Tota l wag e paid	Nu mbe r	Num ber of Days	Wag e/ da y	Tota l wag e paid	Qua ntity	Numb er of days	Wag e/ da y	Total wage paid			
A	C	A	C		A	C	A	C		A	C	A	C		A	C	A	C	
Nursery bed preparation																			
Land preparation																			
Primary tillage																			
2 nd tillage																			
Flooding																			
Transplanting																			
Weedicide application																			
Insecticide application																			
Fertilizer application																			
Scaring																			
Harvesting																			
Drying																			
Bagging																			
Milling																			
Transportation to storage																			

25. Did you use any agro-chemical on the crop. 1=yes () 2=no () e.g. herbicides, weedicides

26. If yes, please indicate the types of agro-chemical used on your crop in the crop year

2012 Major Season -----Quantity(litres)			2011 Minor Season -----Quantity(litres)		
Type of agro-chemical	Major Season	Price/litre	Type of agro-chemical	Minor Season	Price/litre

27. Please indicate the output, sales and self-consumption of the rice cultivated during 2012 major season

Price of output per bag=.....

Plot	Quantity Harvested(bags)		Quantity Sold		Self-Consumption		Bags of rice given as Gifts to friends, relatives, extension agent	
	Number of bags	Type of bag 85kg, 90kg	Number of bags	Type of bag 25kg, 50kg, 85kg, 90kg	Number of bags	Type of bag 25kg, 50kg, 83kg, 84kg,85kg,90kg	Number of bags	Type of bag 25kg, 50kg, 83kg, 84kg,85kg,90kg
1								
2								
3								

28. Please indicate the output, sales and self-consumption of the rice cultivated during 2011 minor season

Price of output per bag=.....

Plot	Quantity Harvested(bags)		Quantity Sold		Self-Consumption		Bags of rice given as Gifts to friends, relatives, extension agent	
	Number of bags	Type of bag 25kg, 50kg, 83kg, 84kg,85kg	Number of bags	Type of bag 25kg, 50kg, 83kg, 84kg,85kg	Number of bags	Type of bag 25kg, 50kg, 83kg, 84kg,85kg	Number of bags	Type of bag 25kg, 50kg, 83kg, 84kg,85kg
1								
2								
3								

Quantity of rice milled.....

29. Cost of services used for 2012 Major season and 2011 Minor season

Types of services	Cost of services for Minor Season	Cost of services for Major Season
Cutting		
Threshing		
Winnowing		
Milling		

Appendix 2

1. Results from STATA 12 Translog Production function

Stoc. frontier normal/half-normal model Number of obs = 1420

Wald chi2(20) = 302.64

Log likelihood = 263.99094

Prob > chi2 = 0.0000

```
-----+-----
      InSscaledOutput |   Coef.   Std. Err.   z   P>|z|   [95% Conf. Interval]
-----+-----
InSscaledOutput      |
InSscaledlabour |  -3.891656   .1600352   -2.43   0.015   -7.028288   -.0755025
InSscaledfert |   .0094686   .1632424    0.06   0.954   -3.104805   .3294178
InSscaledseed |   .854964    .1113195    7.68   0.000    .6367818   1.073146
InSscaledOthercost |  .489098    .1326546    3.69   0.000    .2290998   .7490963
InSscaledMechanization | .2191255   .1202543    1.82   0.068   -.0165686   .4548196
labourSquared |  -1.1964397   .0562186   -3.49   0.000   -3.066261   -.0862532
fertilizerSquared | -.0365367   .0353833   -1.03   0.302   -1.1058868   .0328133
seedSquared |  -1.195266   .0242109   -8.07   0.000   -2.2427185   -.1478136
OthercostSquared |  .0338838   .0221013    1.53   0.125   -.0094339   .0772016
mechanizationcostSquared | -.0016865   .0254947   -0.07   0.947   -.0516552   .0482822
Inlab_Infert |   .0797163   .0327953    2.43   0.015    .0154387   .1439939
Inlab_Inseed |   .0789197   .0340504    2.32   0.020    .0121822   .1456572
Inlab_InOthercost | -.0024623   .0259932   -0.09   0.925   -.053408    .0484833
Inlab_Inmechanisation | .0011779   .024275    0.05   0.961   -.0464003   .0487561
Infert_Inseed |   .0106784   .0337163    0.32   0.751   -.0554043   .076761
Infert_Othercost |  .0253009   .0254464    0.99   0.320   -.024573    .0751748
```

```

Infert_InmechanizationCost | .0621884 .0226278 2.75 0.006 .0178386 .1065381
      Inseed_OtherCost | -.1056523 .0282103 -3.75 0.000 -.1609436 -.050361
Inseed_Inmechanizationcost | -.0402886 .024837 -1.62 0.105 -.0889683 .0083912
InOthercost_Inmechanizatio | -.004208 .0205223 -0.21 0.838 -.0444311 .036015
      _cons | -1.64607 .2611496 -6.30 0.000 -2.157914 -1.134226

```

2. Results from STATA 12 Production Risk function

Stoc. frontier normal/half-normal model Number of obs = 1420

Wald chi2(20) = 302.64

Log likelihood = 263.99094

Prob > chi2 = 0.0000

```

-----+-----
      InSscaledOutput |    Coef.   Std. Err.    z   P>|z|   [95% Conf. Interval]
-----+-----
Insig2v                    |
      SScaledlabour |    1.20063   .1261308    9.52   0.000    .9534178   1.447841
      SScaledfert |  -.8235427   .1409947   -5.84   0.000   -1.099887   -.5471982
      SScaledseed |    .0323226   .1465456    0.22   0.825   -.2549014   .3195466
      SScaledOthercost |    .1012084   .1065641    0.95   0.342   -.1076535   .3100702
      SScaledMechanization | -.2520148   .1015167   -2.48   0.013   -.4509838   -.0530457
      _cons | -4.113303   .1854684   -22.18   0.000   -4.476814   -3.749791

```

3. Results from STATA 12 Technical inefficiency component using the SFA

Stoc. frontier normal/half-normal model Number of obs = 1420

Wald chi2(20) = 302.64

Log likelihood = 263.99094 Prob > chi2 = 0.0000

```
-----+-----
      lnSscaledOutput |   Coef.  Std. Err.   z   P>|z|   [95% Conf. Interval]
-----+-----
Insig2u              |
      Age | .0029571  .0099798   0.30  0.767   -0.016603   .0225171
      Edu_level | .2486741  .1045089   2.38  0.017   .0438405   .4535078
      CREDIT_ACCESS | .4518576  .1815038   2.49  0.013   .0961166   .8075985
      Extvisit | .2224645  .2861104   0.78  0.437  -0.3383017   .7832307
      Gender | -.150555  .1762517  -0.85  0.393  -0.4960019   .194892
      yrsFarming | .0253384  .0171604   1.48  0.140  -0.0082954   .0589721
      Landownership_rented | .170444  .1692419   1.01  0.314  -0.161264   .5021519
```


Familysize	-.010136	.0371069	-0.27	0.785	-.0828641	.0625922
FBOmember	-.9233226	.2110923	-4.37	0.000	-1.337056	-.5095893
MainOccuptn	-.3946705	.2627374	-1.50	0.133	-.9096262	.1202853
Method_of_planting_transplanting	-1.104956	.2357589	-4.69	0.000	-1.567035	-.6428766
Method_of_Landprepararion	1.50802	.3285617	4.59	0.000	.8640509	2.151989
Mode_of_harvesting	-1.160329	.3187538	-3.64	0.000	-1.785075	-.5355826
Region	-2.740603	.384183	-7.13	0.000	-3.493588	-1.987618
_cons	-2.240491	.6082945	-3.68	0.000	-3.432726	-1.048256

4. Results for the test (t –test) between the difference in mean technical efficiency of Greater Accra and Volta Region

Two-sample t test with equal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
Greater	264	.8899398	.0051359	.0834491	.879827	.9000526
Volta Re	91	.6860455	.0148907	.1420486	.6564624	.7156286
combined	355	.8376739	.0071702	.1350961	.8235725	.8517754
diff		.2038943	.0123566	.1795924	.2281962	

diff = mean(Greater) - mean(Volta Re) t = 16.5008

Ho: diff = 0 degrees of freedom = 353

Ha: diff < 0

Ha: diff != 0

Ha: diff > 0

Pr(T < t) = 1.0000

Pr(|T| > |t|) = 0.0000

Pr(T > t) = 0.0000