Assessing Technical, Allocative and Economic Efficiency of Smallholder Maize Producers using the Stochastic Frontier Approach in Chongwe District, Zambia

by

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DECLARATION

I hereby declare that the dissertation I submit for the degree of MSc Agricultural Economics at the University of Pretoria, is my own work and that it has not been previously submitted by me for a degree at this or any other institution of higher learning.

Signed by: _____

Name: MICHAEL KABWE

February 2012

DEDICATION

This dissertation is dedicated to God almighty who art in heaven for his grace, for without his mercies I would not be here today to accomplish this work, and to my wife Sadie and daughter Chambilo for your everlasting support, love and care. You are simply the best.

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ABSTRACT

Smallholder farmers' efficiency has been measured by different scholars using different approaches. Both parametric and non-parametric approaches have been applied; each presenting unique results in some ways. The parametric approach uses econometric approaches to make assumptions about the error terms in the data generation process and also impose functional forms on the production functions. The nonparametric approaches neither impose any functional form nor make assumptions about the error terms. The bottom line of both approaches is to determine efficiency in production.

In this study a parametric stochastic frontier approach is used to assess technical, allocative and economic efficiency from a sample of smallholder maize producers of Chongwe District, Zambia. This approach was chosen based on the fact that production among this group of farmers varies a great deal, and so the stochastic frontier attributes part of the variations to the random errors (which reflects measurement errors and statistical noise) and farm specific efficiency. Using a Cobb-Douglas frontier production function which exhibits self dual characteristics, technical efficiency scores for the sample

of the smallholder maize producers are derived. With the parameter estimates (β_i) obtained from the Cobb-Douglas stochastic production frontier, input prices (W_i) and taking advantage of the self dual characteristics of the Cobb-Douglas, a cost function is derived. This forms the basis for calculating the farmers' allocative and economic efficiency.

Results obtained from the study showed considerable technical, allocative and economic inefficiencies among smallholder maize producers. Technical Efficiency (TE) estimates range from 40.6 percent to 96.53 percent with a mean efficiency of 78.19 percent, while Allocative Efficiency (AE) estimates range from 33.57 to 92.14 percent with a mean of 61.81. The mean Economic Efficiency (EE) is 47.88 percent, with a minimum being 30 percent and a maximum of 79.26 percent. The results therefore indicate that inefficiency in maize production in Chongwe District is dominated by allocative and economic inefficiency. Additionally, in the two stage regression households characteristics: age; sex; education level; occupation; years in farming; land ownership; household size; access to extension and access to credit services; are regressed against technical efficiency scores using a logit function. Results obtained shows that land ownership, access to credit services, access to extension services, land ownership and education level of up to post primary (secondary and tertiary) have a positive influence on the households' technical efficiency. On the other hand, age of the household head; female headed household and lack of education (though not statistically significant at any confidence level) have a negative influence on this group of maize producers. In a similar two stage regression, access to extension services, membership to producer organisation, access to credit and disaster experienced on the farm such as floods, drought and hail, are regressed against AE. The result shows that access to extension services, access to credit services, membership to cooperatives and natural calamities affect AE.

Results therefore show that there is a great deal of both allocative and economic inefficiency among smallholder maize farmers than there is technical inefficiency. To address these inefficiencies observed there is need to design policies that will ensure that environmental (e.g. poor land practices which lead to nutrient depletion from the soils), economic (e.g. high transport cost due to poor road infrastructure) and institutional issues (access to credit) are addressed. In other words, Government should help create credit facilities to provide affordable loans to this group of farmers. Additionally, there is need to

improve extension systems to help educate farmers about better farming practices and other innovative technologies to further improve their efficiency in production. Issues of land ownership among this group of farmers needs to be addressed as this will not only raise confidence but will also ensure that their cost of production is reduced since there will be no need for payment of rental charges, and that farmers will adhere to good farming practices knowing they own title to land.

Key words: Smallholder, parametric approach, efficiency, stochastic frontier production function, Chongwe, Zambia.

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LIST OF ACRONYMS

AE	Allocative efficiency
BAZ	Bankers association of Zambia
BOZ	Bank of Zambia
CD	Cobb-Douglas
CSA	Census supervisory area
CSO	Central statistics office
CFU	Conservation farming unit
EE	Economic efficiency
FNDP	First national development plan
FRA	Food reserve agency
FSP	Fertiliser support programme
GDP	Gross domestic product
Ha	hectare
LME	London metal exchange
MACO	Ministry of agriculture and cooperatives
ML	Maximum likelihood
MT	Metric tonne
NGO	Non-governmental organisations
OLS	Ordinary least squares
SEA	Standard enumeration area
SF	Stochastic frontier
SFA	Stochastic frontier analysis
SFPF	Stochastic frontier production function
SPSS	Statistical package for social sciences
SSA	Sub Saharan Africa
SSF	Small-scale farmer
TE	Technical efficiency
ZMK	Zambian kwacha

CHAPTER 1

INTRODUCTION

1.1   BACKGROUND TO THE STUDY

Zambia's agricultural sector is one of the most important sectors in the economy. This is so because it remains by far the major employer in the economy with almost 70% of the population engaged, contributes between 18-30% to the Gross Domestic Product (GDP) and it is a source of food for both rural and urban dwellers (BOZ, 2010:13). Being a third world country with low literacy levels and majority (*over 70%)* of the population living in rural areas under a dollar per day, it is logical that the country prioritises agriculture.

It was for this reason that soon after independence in 1964 the Government of the Republic of Zambia decided to prioritise agriculture in the quest to try and boost the livelihoods of its people. Thus, for the past five decades the Government of the Republic of Zambia has continued to support agriculture through provision of subsidised inputs, extension services as well as through provision of markets for the farm produce.

Zambia's agriculture production can be split into smallholder and commercial production, according to the Ministry of Agriculture and Co-operatives (MACO) (MACO, 2006:13). This study focuses on the smallholder farmers, defined as farmers who grow crops mostly for domestic consumption. Like any other Sub-Saharan African country, Zambia's agricultural sector is mainly composed of smallholder farmers who constitute a significant proportion of the total farming community because they are the majority of the population (which is unskilled). Thus, the only available sector in such economies which can absorb such large amounts of unskilled labour is the agricultural sector. In fact, 80% of the total farming community in Zambia is smallholder farmers (CSO, 2010:13). By definition, smallholder farmers engaged in subsistence farming usually cultivating land up to twenty hectares while using low levels of technology (MACO, 2006:13).

Viable as they may be, smallholder farmers are largely rural dwellers who are resource constrained and have little or no access to credit facilities due to lack of collateral. With such characteristics, coupled with high transaction costs due to poor infrastructure development, it becomes apparent that smallholder farmers cannot participate effectively in any economic activities unless they are kick started through provision of credit facilities with easy repayment terms. Consequently, Government through an Act of parliament of 1967 formed various organisations to assist in the facilitation of credit services to smallholder farmers which in turn would make them more productive. Thus, since independence, government has been promoting smallholder farming and to date the population of smallholder farmers has grown to the current total of 1,213,749 in 2010 (CSO, 2010:15).

Although smallholder farmers by definition cultivate little land using low levels of technologies, they constitute approximately between 75-90% of the total farming community in Zambia, against just over 10% commercial farmers. MACO (2006:5). In fact, the current statistics shows that there are a total of 1,213,749 smallholder farmers representing 89% of the total farming community in Zambia, with total maize production of 2,488,943 metric tonnes (MT) in the 2009/2010 season. This figure represents an increase in total output of 48% over the 1,887,010 MT produced in the 2008/2009 season (CSO, 2010:10). Smallholder's significant contribution to total output production in the maize sector gives an indication of the important role that they play in the agricultural sector and the economy at large.

Small scale farmers are found in all parts of the country, growing crops like maize, sorghum, millet, cassava, beans, cotton, soybeans, groundnuts, sunflower, paprika, tobacco and potatoes. It is important to note that not all small scale farmers grow the aforementioned crops, but that selection of crops to be grown depends on the immediate use (for instance, food security), location, availability of credit services and access to the market. Of these crops, maize is the most preferred crop among Smallholder farmers (CSO, 2010:31) because it is the country' staple food crop which is highly subsidised and has readily available market which makes it the most affordable crop produced among

smallholder farmers. As a matter of fact almost 80% of the agriculture produce in Zambia is maize while the other crops only comprise up to 20% of the total production.

Among smallholder farmers in Zambia, maize is mostly produced once a year in all the three agro-ecological zones (regions I, II & III) and this is during the rainy season though there are some areas where it is produced twice a year. Areas such as wetlands which are mostly valleys and low lying areas found along river basins (example the wetlands of the lower Zambezi river basin) are among those where maize is produced twice a year. Otherwise, maize production under smallholder is done during warm and wet (rainy) season from November to April. With the ever rising population which puts pressure on available food as well as rising demand for maize to feed into other industries like the beer and animal feed industries, there is need to increase its production. Having acknowledged this fact, Government decided to introduce input subsidies so as to encourage people to produce maize at smallholder level. In fact, Government has in the recent past increased farmers under the subsidy programme to almost eight hundred thousand in the quest to cut down production cost and increase production. Thus, maize production has steadily increased from about 1.2 million metric tonnes in 2002 to 2,488,943 metric tonnes (MT) in the 2009/2010 agriculture season (CSO, 2010).

Although maize is the staple food in the country which is vastly produced, and is highly subsidised with readily available market, the efficiency with which it is produced leaves a lot to desire. That is, while agricultural research stations show that the average yield for maize at smallholder farmer level is between 3.5-5 metric tonnes, the maximum yield that has ever been recorded among this category of farmers is 2.96MT/ha (CFU, 2009:5). In fact, the average maize yield for maize in Zambia during the last 25 years is 1.62MT/ha with a minimum of 0.73MT/ha in 1992 and maximum yield of 2.69MT/ha in 1988 (CSO, 2010:31). The low levels of maize yields warrants the need to conduct a study in order to identify the sources of inefficiency whether it is as a result of Technical inefficiency, Allocative inefficiency or a combination of the two which is Economic inefficiency. Therefore to identify the sources of smallholder inefficiency in maize production, an efficiency study was conducted on a sample of smallholder maize producers drawn from

Chongwe District, considered as being one of the key Districts for maize production in Zambia (CSO, 2010).

Efficiency studies have been conducted by several scholars and researchers in various fields using various methods. Among the researchers who have conducted efficiency studies include and are not limited to Aigner, Lovell & Schmidt (1977), Arega 2003. Battese & Coelli (1988), Battese & Coelli (1992), Battese & Coelli (1995). Battese & Corra (1977), Bauer (1990), Kumbhakar & Tsionas (2006). Kumbhakar & Tsionas (2008), Meeusen & Van Den Broeck (1977), Mouton (2001), Pitt & Lee (1981), Mwila, N'guni & Phiri (1991), and Reifschneider & Stevenson. The main reason for undertaking such studies has been to identify whether firms utilise full capacity in their production processes or not, and to find ways of improving their productivity, as in the case where they have been seen to be less efficient. In economics and other fields, the rationale for the extensive utilisation of efficiency analysis is that firms are hardly totally efficient during production of goods and services. This contrasts the neoclassical view which assumes every firm to be fully efficient, when actually two or more indistinguishable firms cannot possibly produce the equivalent output since their quantity produced, expenses and revenue are different (Kumbhakar, Efthymios &Tsionas, 2006:72).

Firms can either be allocative or technically inefficient in resource use. Firms are said to be technically inefficient when they are unable to obtain maximum output from a given set of input quantities, while they are allocative inefficient when they are not able to utilise inputs in most favourable proportions given their prices and production expertise (Coelli, Rao, O'Donnell & Battese, 2005:4). Thus, the observed difference in output, cost, and profit among identical firms is attributable to technical and allocative inefficiencies, and several unanticipated exogenous shocks (Kumbhakar *et al.*, 2006:72).

The firm's technical efficiency or inefficiency can be determined using either the input oriented (IO) or the output oriented (OO) approach. The input oriented technical efficiency approach expresses a solitary output production technology in which *Y* (a scalar output) is a function of *X* a vector of inputs (Kumbhakar *et al.*, 2006:73). Thus, the IO approach measures the rate at which resources could be used in a production process without

reducing output. The OO technical efficiency shows the rate at which actual output could be increased in a production process while keeping the amount of inputs used constant. Therefore, the OO measure is seen to be the output augmenting measure of TE (Kumbhakar *et al.*, 2006:72).

Efficiency studies are not limited to any particular field. That is, such studies have been applied in various fields which include and are not limited to natural sciences, engineering, agriculture and social sciences. In most of these studies the conclusions has been that firms engaged in production processes are inefficient in their resource use. This particular case, the study is applied to Zambia's agricultural sector with particular focus on the input use efficiency among smallholder maize farmers.

Interesting as these studies may be, none have been used to investigate input efficiency use among smallholder maize producers in Zambia. This is evident from the extensive search of leading journal hosts such as Ebsco, Science Direct, Wiley, etcetera, which showed no evidence of such studies undertaken to date. In other words, most research that has been conducted on small scale maize producers in Zambia is related to farming practices but none points out to efficient use of inputs. Therefore, this study was aimed at analysing TE, AE and EE of smallholder maize farmers using a stochastic frontier production function approach.

1.2 PROBLEM STATEMENT

Food crisis remains everyone's preoccupation, be it at household, national or international levels. Following the World food crisis of 2007 governments' world over, and indeed the Zambian Government decided to further emphasis the need to continue producing staple food crops in addition to cash crops. Maize being a staple food crop which has other uses such as animal feed and as a raw material in beer production, it puts individuals and policy makers on rapid to try and ensure that huge quantities of maize are produced at both household and national levels each season. This poses a challenge for a resource constrained country such as Zambia with limited financial resources, which are to be used efficiently. Over the past decades government has continued to provide subsidised inputs

to smallholder maize farmers so as to make them productive and food secure. Other efforts such as increasing the input packs given to smallholder maize farmers in subsequent seasons have also been made (Zhiying *et al.*, 2008:80). However, much as these efforts to increase input use have been made, no apparent efforts have been made to investigate how smallholder farmers use these inputs.

Additionally, the average national yield for maize is 1.62MT/ha (CSO, 2010:31). Although this figure has varied over the years from the lowest of 0.73MT/ha in 1992 to 2.69MT/ha in 1988 which has been the highest recorded so far, this figure is by far lower than the one recommended at the national level by the agricultural research system. The average recommended national yield for maize produced under small scale is between 3.5-5MT/ha (CFU, 2009:5). This means that in as much as input use, land under cultivation and production has increased, productivity or rather maize yield has remained below the expected 3.5- 5MT/ha. Hence, the need to investigate whether input use inefficiency has played a role in the observed disparities.

Moreover, to determine whether resources are being used efficiently, empirical studies must be conducted. However, extensive search of leading journal hosts such as Ebsco, Science direct, Wiley Inter-science and Google scholar revealed that no such studies have been conducted among smallholder maize producers in Zambia. Consequently, this study was undertaken to investigate the sources of inefficiency in smallholder maize producers as one way of determining whether production can be increased under the same number of farmers and using same production technology.

1.3   OBJECTIVES OF THE STUDY

The main objective of the study was to assess the technical, allocative and economic efficiency of smallholder maize producers in Chongwe District, Zambia. The study was therefore guided by the following specific research objectives:

- To estimate stochastic frontier production functions for smallholder maize producers using the translog and Cobb-Douglas production functions. The translog PF was estimated in order to compare how robust its results compare with that of the CD

frontier for the same sample of farmers. This functional form is deemed flexible and computationally straightforward.

- To measure technical, allocative and cost efficiency of individual farming units using the Cobb-Douglas production functions.

- To assess the main determinants of efficiency among smallholder maize producers in Chongwe District.

- To prescribe a policy proposition for smallholder maize producers based on the results of the efficiency analysis.

1.4 IMPORTANCE AND BENEFITS OF THE STUDY

Having acknowledged the importance of maize production at both household and national level warranted the need to conduct the study. This study was designed to help find solutions which would contribute to increasing its productivity as well as production. By so doing the study contributed to both the stakeholders in the maize sector and the researcher. Therefore, this study has important benefits to the researcher, smallholder maize producers, policy makers in government as well as an important contribution to the body of knowledge in production economics. To the researcher, the study was a very eye opening one in that it assisted in understanding more about Zambia's agriculture, smallholder farming as well as maize production. Particularly, conducting this study taught the researcher how to conduct efficiency analysis studies using the parametric approach, how to derive AE and EE using the CD production function, and how to use results/research findings to recommend policy interventions

Moreover, identifying inefficiency in smallholder maize production helps smallholder maize producers to use their inputs efficiently thereby helping in economising the already scarce resources in the country. That is, if smallholder farmers can increase productivity with same input quantities then the savings made by government from the restricted spending can be used for other developmental projects such as in health and education. Thus, the study will help smallholder maize producers to make optimal input combinations which will increase their overall efficiency. Additionally, results of this study will help policy makers to

design policies that will make their enterprises more profitable. Policy makers will also use the results to target interventions according to the perceived needs of smallholder maize producers.

Moreover, the results obtained from this study will contribute to the already existing body of knowledge in production economics and efficiency studies in particular. That is, the outcome of this research study will be used to justify the need for conducting efficiency studies. Based on the production behaviour of small scale maize producers to be characterised from this study, an insight will be given on the general trend that is expected of in this particular group of farmers anywhere else.

1.5   ASSUMPTIONS ADOPTED IN THE STUDY

The proposed research study was based on the following assumptions:

- Data collected and the measurement mechanisms provided the accurate representation of the actual inputs used by smallholder maize producers in the production process.

- Sample of smallholder maize producers provided a true representation of population from which the sample was drawn.

- The relationship between the inputs used in the production process and the output obtained was correctly specified.

- Data was collected with minimal measurement errors to avoid endogeneity problems

1.6   DEFINITION OF KEY TERMS

Key terms used in this research proposal are defined as follows:

Allocative Efficiency: Allocative efficiency is the firm's ability to use inputs in optimal proportions given their respective prices and production technology (Coelli, Rao, O'Donnell & Battese, 2005:5).

Chitemene system: refers to the slash and burn kind of farming system commonly practiced among Zambian communities. This kind of farming involves indiscriminately cutting down of trees which are heaped then later on burnt down to produce ash which acts as fertiliser and on which crops are planted (CFU, 2009:11)

Commercial farmers: are farmers who cultivate above twenty hectares of land and mostly produce for selling using sophisticated technologies (MACO, 2006:6).

Endogeneity is found in econometric models and arises as a result of measurement errors, autoregression with autocorrelated errors, simultaneity, omitted variables, and sample selection errors (Gujarati, 2003).

Floor price: term commonly used in the agricultural sector referring to the price set above the equilibrium market price in order to absorb excess commodity supplied on the market by the supplier/producer. Excess commodity on the market occurs when the quantity demanded (Q_d) is less that quantity supplied (Q_s) causing pressure on the producer to reduce commodity supply. However, in order to prevent the supplier from reducing production the government or its agency pays the producer a higher price as an incentive to continue producing and supplying the commodity on the market, then absorbs the excess commodities from the market.

Medium-scale farmers: these are farmers who cultivate land more than five hectares but less than twenty hectares, mainly produce for household consumption using low levels of technology and tend to sell the surplus produce.

Production Frontier: This specifies maximum outputs for given sets of inputs and existing production technologies or defines minimum costs given output levels, input prices and the existing production technology, in the case of a cost frontier (Reifschneider & Stevenson, 1991:1).

Small-scale farmers: refers to farmers who cultivate up to five hectares of land, mainly produce for household consumption using low levels of technology and tend to sell the surplus produce (MACO, 2006:6).

Technical Efficiency: Technical efficiency refers to a firm's ability to obtain maximum output from a given set of inputs quantities (Coelli, *et al.*, 2005:5).

1.7   DATA, METHODOLOGY AND RESEARCH AREA

Both primary and secondary data was used in this study. This data contained production related variables as well as the demographic and the socioeconomic characteristics of the sampled households. Primary data was collected using a semi-structured and detailed questionnaire which was administered to a sample of smallholder maize producers who were selected using both the stratified and purposive sampling methods. The purpose of the questionnaire was to collect all relevant information regarding parameters that enter in the production of maize (which included both inputs used in the production process and the output obtained from those inputs), which was used to measure efficiency. The vital information collected included amount of fertiliser applied per unit area, sources and quantity of labour for production, other supplementary inputs in the production process, *etcetera*. Prior to actual data collection, the questionnaire was pre-tested on a few respondents to check for the possible errors that could affect the quality and accuracy of data collected.

Secondary data which acted as supplementary data was collected from MACO and CSO as these are the organisation that collects data annually from this group of farmers for statistical purposes. This data was used for comparisons sake. Other sources of secondary data were co-operatives and NGOs which work closely with the farmers. The primary data collected was transcribed on to MS Excel spread sheets from which summary statistics were obtained using MS Excel for the purpose of verifying that there were no possible outliers that would affect the results. Both measures of central tendency like the mean and the measures of dispersion such as the standard deviation were obtained. Data coding and definition of variables was done using SPSS and EViews. Derivation of the

stochastic frontier production functions and measurement of efficiency was done using frontier v4.1 while the two-stage regression (logit) model was run in Stata.

The study was conducted in Chongwe district of Zambia located in Lusaka province, about 50 kilometres east of Lusaka city. The area is mostly plateau with land between 900-1500m above sea level and located in agro-ecological zone II. The average annual total rainfall received is between 800-1000 millimetres making it ideal for maize production. The district has a total of 12 SEA with 1500 households who are actively participating in small-scale agriculture (CSO Report, 2010:6). This area makes an ideal place for conducting the study because: firstly, it is located in the agro-ecological zone II which has ideal weather conditions for maize production. That is, the area receives favourable amounts of rainfall for the crop to reach physiological maturity and has rare cases of floods and/or droughts which may affect crop yields. This makes it easy for the researcher to rule out the influence of bad climatic conditions on the crop yield. Secondly, most farmers in the area have previously benefited from subsidised inputs provided by government which gives them equal access to input.

The district is actually made up of two distinctive areas: the productive belt located on the western side of the district which is relatively flat land, has good fertile soils and receives good rainfall, and the less productive area located on the eastern side which is mountainous and borders with region I. Thus, household settlement is such that more households are in villages located in the more productive area than they are in the less productive area. Among the sampled villages from the more productive belt are Chiyalusha, Bunga, Shibale and Shamboshi while Kampekete, Kwale, Muteba, Mwakaule, Saiti and Sekelela which are located in the less productive area. Households from the less productive area were categorised as 'other' and had a combined total of 27 households.

In terms of maize production, all of it is produced under rain fed except in few isolated low lying and valley areas located on the southern part of the district. Like in other parts of the maize in Chongwe district begins with input sourcing. This normally commences upon selling of the previous stock of maize around July and August. There are various sources of inputs for the smallholder farmers, these include subsidised inputs programme by the

government's FSP, NGOs, co-operatives, own supply and others such as the private suppliers. Under FSP, NGOs and co-operatives, limited quantities of inputs are received by farmers and may have a specific period during which a household can benefit from such subsidised inputs. This differs when farmers source money and buy directly from an outlet or when they engage into contract with private suppliers. Private input suppliers are usually individuals who supply inputs to smallholder farmers on credit where the repayment is in form of grain at harvest time. Inasmuch as they mitigate inputs supply to smallholder farmers this category of input suppliers usually exploit the farmers as they usually take advantage of the farmers' limited negotiating skills to reap a fortune out of them.

Commencement of an agricultural growing season begins at the onset of rainfall which is usually around mid October to late November. The length varies depending on size of land to be cultivated and labour availability. Land preparation is immediately followed by seed planting and the length of this activity equally varies with labour availability though the rule of thumb is to finish planting by Mid December. Split application of fertiliser is a common trend among this category of farmers and application starts with compound fertiliser which is normally applied between 14 days and 28 days after germination or when the crop is at knee height by convention. Nitrogen fertiliser is usually applied after eight weeks or when the crop is near sprouting.

Weeding is usually done twice during the entire production cycle but this depends on the amount of rainfall received and the number of times that a particular land has been cultivated. That is, if the land is relatively virgin and moderate amounts of rainfall are received within a given period of time then weeding can be done once. However, if a piece of land is utilised for maize production every other season then weeding can be done more than twice. The length of weeding depends on land size and labour availability. Thus, the bigger the field and the fewer the man power, the longer it will take to remove weeds from a given field. Harvesting is normally done once the crop reaches physiological maturity and this takes between 120-150 days of five months at most depending on whether a household planted early of late maturing varieties. This equally varies among different farmers due to the fact that they plant at different times, have different land sizes, different

labour requirements and different know-how as regards maize production. The quantity harvested by each household also varies as it largely depends on the area harvested in addition to the aforementioned factors. Even when the area harvested is the same total quantity may still differ due to differences in crop management capability which has a direct bearing on the productivity per unit area.

1.8   ORGANISATION OF THE THESIS

This dissertation comprises six chapters. The introductory chapter has just been discussed and is the first chapter, while chapter two reviews the agricultural policies and programmes in Zambia that have impacted farmers' productivity. Chapter three reviews literature on efficiency: how it is measured as well as the empirical applications to the measurement of efficiency within the context of the agricultural sector. Chapter four describes the study area, survey instrument, survey implementation as well as the socioeconomics characteristics of the sampled smallholder maize farmers. Results and discussion of the results are done in chapter five, while conclusion and policy implications are included in chapter six which is the final chapter of this dissertation.

CHAPTER 2

REVIEW OF THE ZAMBIAN AGRICULTURAL POLICIES AND PROGRAMME CHANGES AND THEIR IMPACT ON FARMERS' PRODUCTIVITY

2.1   INTRODUCTION

This chapter highlights how the various policy changes in Zambia's agricultural sector have affected the farmers' productivity patterns overtime. Zambia's agricultural policies as well as programmes to spearhead policy implementation have been dynamic since independence. Basically, there has been three major policy shifts in the agricultural sector which also correspond with the different production pattern mostly among the smallholder maize producers over time. Before highlights of policy changes are given, the chapter begins with a general overview of the agricultural sector in Zambia, followed by farmers and farming techniques, contribution to GDP, credit schemes, significance as well as challenges faced in the sector is given in this section 2. This will then be followed with a section 3 which gives the geographical overview of Zambia, after which section 4 discusses and highlights the evolution of agricultural policy in Zambia over time. Section 5 which is final section of this chapter will give the conclusion of the chapter by highlighting major points.

2.2 OVERVIEW OF THE ZAMBIAN AGRICULTURAL SECTOR

Agriculture in Zambia can be divided into two eras, namely the colonial and the post colonial. Before Zambia gained its independence, agriculture was largely dominated by white farmers who received credit and other support services from the then federal government (FNDP, 1970:12). The indigenous on the other hand participated in agriculture using traditional methods of farming such as *chitemene* system. After independence the government of Zambia decided to promote agriculture among the black communities

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based on the new policies that were designed and put in place at the time, and did this through the provision of inputs and other credit facilities to the local farmers (FNDP, 1970:14).

2.2.1 <u>Zambian farmers and farming techniques</u>

The then ministry of agriculture, food and fisheries, (now known as the ministry of agriculture and cooperatives) categorised farming into smallholder and commercial production. The former was further classified into small-scale and medium-scale production. To date small-scale production is done by small-scale farmers. This category includes farmers who cultivate up to five hectares of land. Medium-scale production, on the other hand, is done by medium-scale farmers who equally produce for household consumption using low levels of technology; tend to sell the surplus produce and are farmers who cultivate land more than five hectares but less than twenty hectares. Commercial production is usually done by large scale farmers who mostly produce for selling using sophisticated technologies, and these refer to any farmer who cultivates twenty hectares of land or more. The other category includes institutional farms, but its discussion is not relevant to this study (MACO, 2006:13). Table 1 below shows the categories into which the Ministry of Agriculture in Zambia has divided the agricultural sector for statistical purposes.

Table 1:   summary of farmer categories in Zambia

FARMER CATEGORY	HECTARAGE
Small-scale	less than 5 ha
Medium-scale	5 to 20 ha
Commercial	20 + ha
Institutional	20 + ha

Source: Ministry of Agriculture and Co-operatives report (2006:13)

Currently there are a total of 1,213,744 small scale farmers and 1,111 large scale farmers in Zambia cultivating 2 million hectares of land and producing a combined total of 2,795,483 MT of maize (Central Statistics Office, 2010:31).

2.2.2 Zambian government's role in promoting agriculture

Because of the significant role that agriculture plays in the growth and development of the economy, the government of Zambia has continued to support the sector so as to achieve the vision of being food self sufficient. These support services range from provision of subsidised inputs to market creation for the farm produce. Agricultural subsidies play a major role in augmenting the country's agricultural productivity. This is so because subsidies lower input costs which makes it affordable for low income rural households. Among the inputs subsidised for smallholder maize farmers in Zambia are fertiliser and seed.

Access to inputs by smallholder farmers imply increased agricultural productivity which in turn improves their income and food security. Agricultural subsidies also play a role in lowering and stabilising market food price making it affordable to all. In fact, input subsidies have a positive effect on the household productivity, market price stabilisation and overall household food security. Subsidised inputs are provided by the government through the Fertiliser Support Programme (FSP)

Moreover, it is the duty of the government to provide market for the farm produce by way of creating market outlets. This is done in order to promote and encourage production. Thus government through the Act of parliament of 1967 has created various marketing boards to provide market for the farm produce (FNDP, 1970:14). Currently, the Food Reserve Agency (FRA) is mandated to provide such services to the farmers. FRA also sets the 'floor price' for the crops in addition to market provision. Other additional players in the maize market are the millers and private maize traders. Although they play a role in ensuring market creation especially for the farmers in the remotest parts of the country, private maize traders often offer exploiting prices.

The government equally provides extension services to the farmers through the Ministry of Agriculture and Co-operatives (MACO). This is done to educate farmers on better agricultural practices with regard to land tillage systems, input use and good marketing skills.

2.2.3 Production over time and contribution to GDP

Production over time

Agriculture production during the period 1964-1991 was centred around maize production as maize was deemed as the staple food crop. To this effect government provided many incentives so as to encourage its production even in areas which are not conducive for maize production (Chizuni, 1994:46). Thus, during this period maize production was generally on the rise as can be seen from Figure 1. However, promotion of maize production among smallholder farmers was being done at the expense of other crops. This resulted in a shift in the production trend which led to abandoning of traditional crops such as cassava, millet and sorghum for maize production. Cash crops such as tobacco and cotton were mostly produced by large scale farmers.

Figure 1: Annual maize production (in kilogram's) from 1965 to 2010
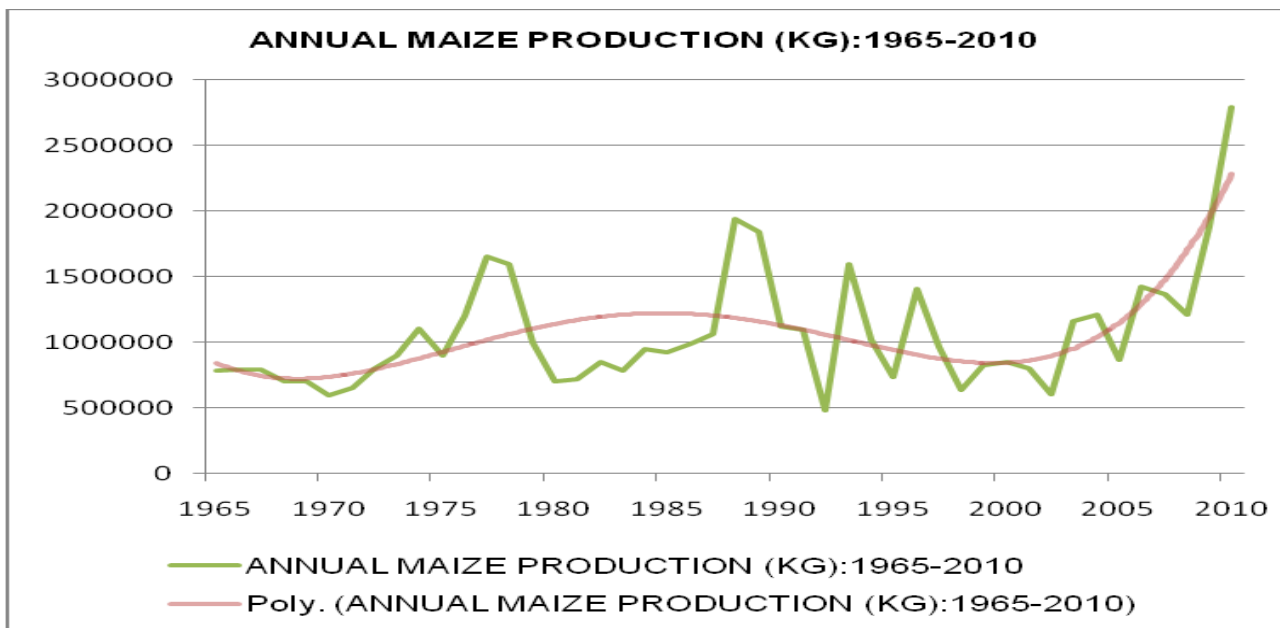
Source: CSO Crop forecast report 2010

Period 1991-2001, saw liberalisation of the agricultural sector as well as policy shift from that of highly promoting maize production through subsidies to that of encouraging farmers to produce crops that are adaptive to their different agro-ecological zones (I,II and III).

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Thus, maize production during this period took a 'nose dive' reaching the lowest production ever recorded in the country.

In 2002, government re-emphasised the important role that agriculture plays in the growth and development of the economy and saw the need to make it competitive and diversify it away from maize production (Chizuni, 1994:47). Thus, during this period the policy was tailored to encourage public private partnership. This saw the emergence of NGOs and donor agencies participate in the expansion of the agricultural sector. With the incentives being offered by government through FSP and FRA, maize production has increased in the country reaching the highest ever recorded annual production of 2,795,483 MT in 2009/2010 farming season. Figure 1 shows the trends in Zambia's annual maize production. In this figure, the green curve shows the actual maize production trend from 1965 to 2010 while the red (polynomial) curve depicts the general trend in maize production during the period the same period. From the figure, it is clear that maize production rose during the periods 1964-1991 and 2002 onwards while it declined in the period 1992-2001. This decline in the annual maize production during the 1992-2001 could be attributed to reduced government's support to the agricultural sector.

Contribution to GDP

The DFID (2002:6) report on the assessment of Trends in the Zambian Agricultural Sector revealed that the sector's contribution to real GDP averaged 18% during the period 1991 to 2001, and 39% of this were earnings from non-traditional exports. Jansen and Rukovo, (in DFID, 2002) also reported that during the 25 years post independence period (1964-1990), marketed crop production increased at an average annual production rate of 2.5%. However, this growth in crop production was below the population growth rate of 3.7 per cent making the country vulnerable to food insecurity.

The period from 1990 to 2000 recorded a much more positive agricultural growth at around 4.5% which exceeded average population growth of 2.6% (World Bank, 2002). This could be attributed to the fact that agricultural policy advocated for crop diversification as opposed to single (maize) crop production. Much as the period 2002 onwards has

recorded growth in annual food crop production, lack of emphasis of on production of food security crops such as maize, cassava, sorghum and millets led to the country's increased vulnerability to poverty, malnutrition and general household food insecurity.

2.2.4   Other sectors contributing to GDP

Mining is Zambia's main economic driver. This makes the Zambian economy to be largely dependent on mining of copper ore which is actually the main export. As a matter of fact, Zambia is one of the major copper producing and exporting countries in the World currently ranking ninth with a total annual production of 700 000 metric tonnes and holds 6% of the World's total reserves. Copper exports accounts for over 70% of the country's total exports (Standard Bank Zambia, 2010:12).

However, the revenue earned from copper exports is largely dependent on the World prices, meaning that any drop in prices at the London Metal Exchange (LME) greatly affects local earnings. This was the case especially around the 1970s, 2008 and in 2009 when copper prices drastically fell to below expectations which made it difficult for the country to finance most developmental projects (Chomba, 2004:11; Standard Bank, 2010:13). Thus, the lethargic growth in the Zambian economy can partly be attributed to over dependence on copper production forsaking other sectors that could have given the country other impetus to grow (Chomba, 200:11).

In as much as copper production and exports have increased, its price at LME continues to be volatile. This has made it rather difficult for the government to continue depending on copper for its economic growth and development. Hence, the increased focus on agriculture.

2.2.5   Significance of Agriculture

Agriculture offers the best alternative to mining in Zambia. It in fact plays a very crucial role in the growth and development of the economy as can be seen from its total contribution to

GDP which has been between 17-25% over the years. Specifically, agriculture continues to play a significant role in the economy in that:

- it provides employment to most rural households who are directly involved in farming;

- it is the primary source of food for the country's populace which comes as a result of increased production leading to increased supply and sequential reduction in general food prices making it affordable to all (Chomba, 2004:11);

- It is a potential source of foreign exchange for the country, which is partly used to offset the balance of payments deficit (Chomba, 2004:11);

2.3   LOCATION, PHYSICAL AND GEOGRAPHICAL OVERVIEW OF ZAMBIA

Zambia is located in the southern part of Africa between latitudes 8 and 18 degrees South of the equator and between longitudes 22 and 36 degrees east. It covers a total area of about 752,000 square kilometres (Chomba, 2004:9). In terms of geographical features, Zambia is divided into three topographical features, namely land below 900 metres above sea level which cover the low lying and valley areas; land between 900-1500 metres above sea level which covers the plateau; and land above 1500 metres above sea level which is mainly mountainous area (Mwila, Ng'uni & Phiri, 2008:1).

Climate wise there are three distinct seasons which include: Cold and dry season from May to August; Hot and dry season from September to November; and Warm and wet season from December to April. Small scale farming occurs in the warm and wet season as crop production is highly dependent on rainfall as opposed to irrigation and that this is the season when conditions are most favourable for farming (Mwila *et al*., 2008:2). With regard to the natural balance, the country is divided into three ecological zones which are sometimes referred to as the agro-ecological zones (Chomba, 2004:9). These are:

- Agro-ecological zone I (also referred to as Region 1) which receives rainfall below 800 millimetres. This covers the southern part of the country consisting of low lying and valley areas;

- Agro-ecological Zone II, also referred to as Region 2, receives rainfall between 800 and 1000 millimetres, located in the central part of the country and covers the plateaux;

- Agro-ecological Zone III, also referred to as Region 3, receives rainfall above 1000 millimetres and covers the northern part of the country.

Figure 2: Agro-ecological zones of Zambia.
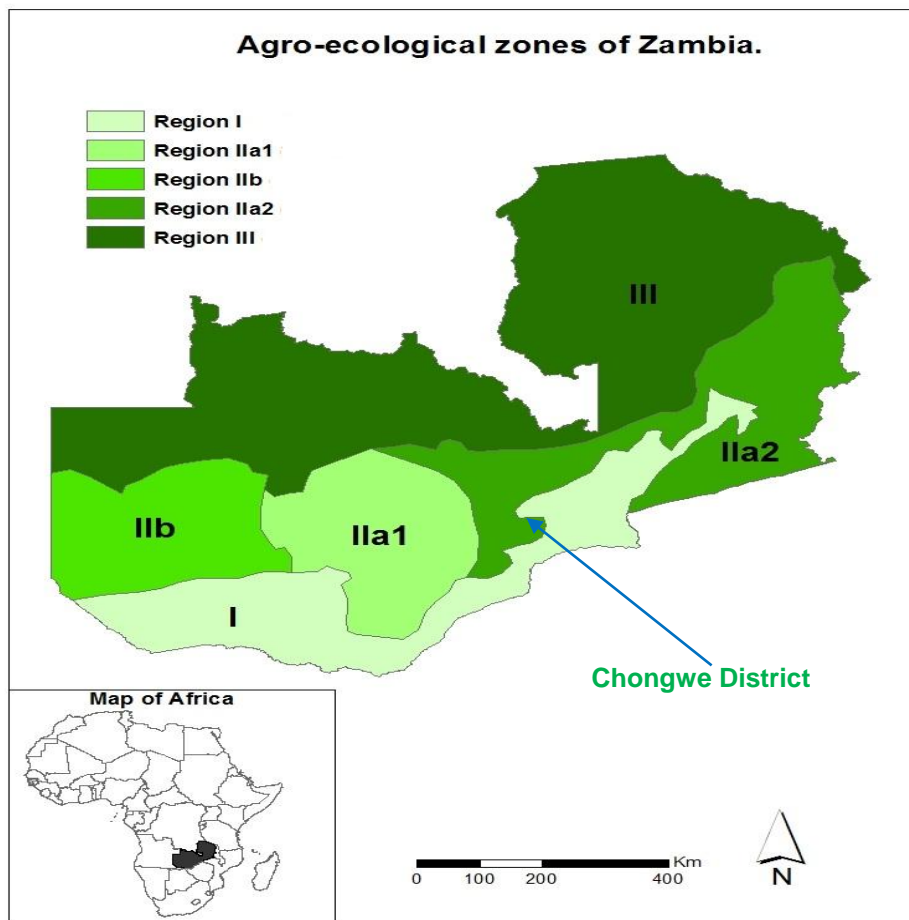
Source: Thurlow et al., (2008).

Of the three agro-ecological zones, zone 2 receives the most favourable amount of rainfall and has good fertile soils which are ideal for crop production. Thus, most agricultural activities take place in this region. Figure 2 shows the locations of these agro-ecological zones.

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As regards political boundaries, the country is divided into provinces, districts and wards. Provinces are the largest administrative units while wards are the lowest administrative units in the country. There are a total of nine provinces and 73 districts in Zambia. In addition to the above divisions, Zambia's Central Statistical Office (CSO) has further subdivided each ward into Census Supervisory Areas (CSA) and Standard Enumeration Areas (SEA) for the purpose of sampling. The SEA is the smallest area with well-defined boundaries identified on a census sketch maps. Each SEA contains approximately between 100-150 households (Central Statistics Office, 2010:6)

Table 2:   Zambia's population distribution

Age	Male	Female	percentage of Population
0-14	2,659,572	2,634,379	45.30%
15-64	3,045,536	3,053,465	52.30%
65+	115,662	160,920	2.40%
Total	**5,820,770**	**5,848,764**	**100%**

Source: Zafar, (2008:9)

In terms of population, Zambia has 11,669,534 million people of which 45% of the population is less than 14 years old while 52.3% are between 15-64 years of age and only 2.4% is 65 years and above (Zafar, 2008:9). Up to 81% of the population is literate. However, only 20% of the total population is in the formal employment giving the unemployment figure of 70-80%. Thus, majority of the population live in the rural part of the country where they thrive on agriculture for their livelihood. Table 2 shows a summary of Zambia's population distribution.

2.4 EVOLUTION OF THE AGRICULTURAL POLICY IN ZAMBIA OVER TIME

Having acknowledged the important role that agriculture plays in the economy, government of Zambia in conjunction with donor agencies and the private sector with whom it closely collaborates has been designing and implementing policies to help in this quest. Consequently, three major agricultural policy changes have occurred since independence. During the period 1964 to 1991 government designed a policy which

ensured food security through increased crop production and availability by providing high producer prices for various crops, especially maize.

In the period that followed (1992-2001), and with the coming in of structural adjustment programmes (SAP) government decided to change the policy where agricultural production and marketing was liberalised. This meant that government no longer subsidised inputs for the producers and that supply of these inputs was left in the hands of the private sector (Chizuni, 1994:46). For the period 2002 to 2015, the overall Agriculture Policy aims at facilitating and supporting the development of a sustainable and competitive agricultural sector that assures food security at national and household levels and maximizes the sector's contribution to GDP (MACO, 2004:6).

2.4.1 Agricultural Policy: 1964-1991

The agricultural policy between 1964 and 1991 was characterized by government controls through parastatals, cooperatives and other government supported institutions to deliver agricultural services and, to some extent, direct production of commodities (Hantuba, 2003).According to Chizuni (1994:46), the policy was designed so as to encourage maize production throughout the country - even in regions which were not suitable for maize production. And to achieve this, government provided attractive incentives like uniform prices for inputs (fertilizer, seeds and agricultural chemicals) and uniform crop producer prices. Besides providing high crop producer prices government's policy was to also keep the prices of processed agro-products such as maize meal, cooking oil etcetera, as low as possible. This was done through the introduction of "Price differential subsidy". For instance, maize buyers paid farmers a uniform price for the bag of maize regardless of the distance and sold the same bag of maize to the miller at a slightly lower price while they claimed the difference from government as the price differential subsidy.

Additionally, in the case where processors fixed economic prices for their products, government requested them to reduce such prices and advised them to claim through consumer subsidy the difference between the economic price and the government controlled price (Chizuni, 1994:46). While these incentives resulted in increased

production of maize and other crops in the subsequent years, it costed the country huge amounts of money which negatively affected the economy. Consequently, the economy grew weaker and weaker, making it increasingly difficult to finance such heavy producer and food subsidies which further resulted in very huge budget deficits (Chizuni, 1994:46).

During the period from 1964 to 1991, parastatals and other state controlled institutions acted as the drivers for policy implementation (Hantuba, 2003). In other words, government created such institutions in order for them to provide all the services that were provided for in the policy. For instance, the government created Nitrogen Chemicals of Zambia (NCZ) and Zambia Seed Company (Zamseed) through an Act of Parliament to produce and supply fertilisers and seed which government supplied to the farmers at subsidised rates to enhance crop production. Government also created various financial lending institutions to provide low interest agriculture loans, latest of which was the Lima Bank which provided such services to farmers.

2.4.2 Agricultural policy: 1991-2001

The government that came into power in 1991 decided to do away with the previous regime's agricultural policy. Whereas, in the previous government both agriculture production and marketing was strictly controlled, the new government decided to liberalise both production and marketing (Chizuni, 1994:46). According to Hantuba (2003) "the government embarked on agricultural policy reforms as part of the economic structural adjustment programmes (SAP) where the main focus of the policy reforms was to liberalise the agricultural sector and to promote private sector development and participation in the production and distribution of agricultural goods and services. Agricultural policy endeavoured to create an enabling environment for private sector participation through measures such as withdrawal of direct government involvement in production, marketing and distribution of inputs and produce, privatisation of parastatal companies, elimination of price controls and direct subsidies in the sector". Objectives of the agricultural policy were:

- To ensure nation and household food security through dependable annual production of adequate supplies of foodstuffs at competitive cost.

- To ensure that the existing agricultural base was maintained and improved upon.

- To generate income and employment through increased agricultural production and productivity.

- To contribute to sustainable industrial development by providing locally produced agro-based raw materials.

- To increase agricultural exports thereby enhancing the sector's contribution to the national balance of payments.

The strategies for attaining these policy objectives included among other things the strengthening and monitoring of the liberalised markets, facilitation of the private sector development, and diversification of agricultural production particularly among small holder farmers. The review and realignment of institutions and legislative arrangements was a critical policy objective (Hantuba, 2003).

Through liberalisation as well as elimination of state involvement in production, marketing and distribution of agricultural products, government was encouraging farmers to grow crops that were ecologically adapted to their respective regions (high rainfall, medium rainfall and low rainfall regions). This was contrary to the previous policy that promoted maize production in all regions. Thus, farmers who lived in low rainfall areas were encouraged to grow drought tolerant crops like sorghum, millet, cassava, ground beans and other food crops, while those in medium to high rainfall areas were also being encouraged to grow crops which adapted to such area (Hantuba, 2003). Although this resulted in crop diversity, it had a negative effect on the quantity of maize produced in the subsequent years (Hantuba, 2003).

During the period 1991 to 2001, the main vehicle for the implementation of these policy objectives in agriculture was the Agricultural Sector Investment Program (ASIP) under the Ministry of Agriculture, Food and Fisheries (MAFF). ASIP adopted a holistic approach to provide improved and sustainable services to the sector through efficient use of resources. The major underlying assumption was that all government and donor resources would be pooled into a "basket funding" for the various ASIP activities. The strategies for achieving

the objectives of ASIP focused on enhancing production through free market development, reduction of government role in commercial activities, and provision of efficient public services.

The interventions of ASIP were organized around the sub-programs like extension, Irrigation, research, agriculture training, animal production and health, agriculture finance, marketing and trade, seeds, new product development, farm power and mechanization, policy and planning, standards, and the rural Investment fund. These sub-programmes set the outline of the Ministry of Agriculture, Food and Fisheries (MAFF) during the period 2006-2010. Consequently, the ministry was restructured to meet the objectives of the program. During this period the program scored a number of successes and recorded some failures. (GRZ/MAFF ACP, 2001).

2.4.3 Agricultural Policy: 2002-2015

"The main focus of the agricultural policy for the period is to facilitate and support the development of a sustainable and competitive agricultural sector that assures food security at national and household levels and maximizes the sector's contribution to Gross Domestic Product" (MACO, 2004:6). To achieve this, the following specific priority objectives have been set:

- To ensure national and household food security for up to 90% of the population by 2015 through an all-year round production, and post-harvest management of adequate supplies of basic foodstuffs at competitive costs.

- To contribute to sustainable industrial development by providing locally produced agro-based raw materials.

- To increase agricultural exports thereby enhancing the sector's contribution to the National Balance of Payments.

- To generate income and employment through increased agriculture production and productivity, and

- To ensure that the existing agricultural resource base is maintained and improved upon.

The policy targets for the period include:

- Increasing agriculture's foreign exchange earnings from the then current earnings of 5% to 20% by 2015.
- Productivity augmentation from the annual rate of 1-2% to 7-10% in order to expand output
- Increase agriculture contribution to GDP & agriculture incomes from the current GDP contribution of 18-20% to 30 %

The policy strategies which have been put in place in order to achieve the aforementioned policy objectives include the private sector led market development in which the private sector is expected to collaborate with government through the public private partnerships. The government on the other hand has pledged to focus on infrastructure development and support services. The policy instruments include public expenditure, taxes and trade restrictions and provision of incentives (Govereh & Weber, 2008)

Therefore, the main emphasis of the policy for this period is the need to make Zambian agriculture competitive and diversified away from maize, encourage public private partnership and make the private sector (in particular through the out grower schemes) have a strong role in the development process of the Zambian agriculture. Policy also highlights the need for adoption of farming practices, which are both economically and environmentally sustainable (Hantuba, 2003).

The policy emphasis for the period was to diversify the agricultural sector and promote an all year round production of both food crops and cash crops, though this meant ensuring enhanced food security among the smallholder farmers both at household and national level ensuring food security before diversifying production into other high value crops became everyone's primary concern. The outcome of the this policy has so far seen an ever increasing annual maize production to ensure both household and national food security as well as increase in the production of other crops.

As for the 2004-2015 the main drivers of policy implementation are the public private partnership where government through FSP provides subsidised inputs, marketing through

FRA and extension services through MACO, while the private sector complement government's efforts through promotion of out growers schemes especially in tobacco and cotton production, provision of seasonal agriculture credit and technical advice. The NGOs and donor agencies have been instrumental during this period.

2.4.4 Challenges

A lot of policy challenges have been noted in the Zambian agricultural sector over time. The agricultural policy in Zambia has been primarily aimed at food security, poverty reduction, and the promotion of cash crops mainly as non-traditional exports (MACO 2002). The PRSP notes 'inconsistency between policy pronouncements and implementation', and the historical lack of clarity in agricultural policy which has weakened private/public sector partnership and created uncertainness in agricultural production and marketing. Current agricultural input and output marketing, rural/microfinance, and agribusiness development (processing, agro-service provision such as mechanisation etc.) need to be improved (PRSP), and the sector is served by weak public sector institutions and legal/regulatory environment (DFID 2002:14).

2.5 CONCLUSION

In the past five decades Zambia's agricultural policy pronouncements and implementations have been dynamic. Three major policy changes have occurred during the same period. Basically, the agricultural policy has shifted from that of being state controlled with heavy input/price subsidies and price controls, to that of free market economy and liberalisation with the major emphasis on crop diversification among smallholder farmers, and finally to that of enhancing public private partnerships.

What has been notable is that during all the three phases of policy changes is that government has been creating parastatals and institutions to spearhead policy implementation. Moreover, all these policy changes have had their own unique challenges in terms of implementation as well as ability to achieve the desired policy goals.

CHAPTER 3

LITERATURE REVIEW ON EFFICIENCY, MEASUREMENT AND EMPIRICAL APPLICATIONS IN THE AGRICULTURAL SECTOR

3.1 INTRODUCTION

In this chapter, the objective is to define and give an overview of theoretical literature on efficiency and frontier models, stochastic frontier approach in measuring efficiency as well as give evidence of empirical studies on efficiency. In the section that follows the concept of efficiency, its measurements as well as background are presented. Section 3.3 discusses the empirical literature which is subdivided into two, namely empirical studies in agriculture and the specific empirical studies in African agriculture sector. Section 3.4 gives details of the models adopted for the studies which include the translog and the Cobb-Douglas frontier functions. The chapter will end with a conclusion in section 3.5.

3.2 THEORETICAL LITERATURE

3.2.1 <u>The concept of efficiency and its measurement</u>

In microeconomic theory, a production function is viewed as a technical relationship which depicts transformation of inputs into output (Battese & Coelli, 1992). It is also defined in terms of maximum output that is attainable from a given set of inputs. Maximum output attainable in a production process is what gives rise to certain concerns in economic theory which includes efficiency with which economic agents produce such outputs. To measure this efficiency, a production frontier function is derived which depicts the maximum output as a function of input set. In the same line of thought, a cost frontier function depicts the minimum cost as a function of input prices and output (Coelli, Rao, O'Donnell & Battese, 2005:5). The term efficiency therefore becomes a relative measure of a firm's ability to utilise inputs in a production process in comparison with other firms in

the same industry. It is relative in the sense that comparisons of efficiency scores are made relative to the best performing firm in the same industry. Similar assertions can be made with regard to cost efficiency. In economics and other fields a firm's efficiency can be viewed in terms of technical efficiency, allocative efficiency and economic efficiency.

A firm is said to be technically efficient in its production when it produces maximum quantity of output from a given set of input resources. On the other hand, allocative efficiency is the firm's ability to use inputs in optimal proportions given their respective prices and production technology (Coelli *et al.*, 2005). In order to calculate the firm's different efficiencies, there is need to have knowledge of the production frontier. A production frontier specifies maximum outputs for given sets of inputs and existing production technologies or defines minimum costs given output levels, input prices and the existing production technology, in the case of a cost frontier. Thus, knowledge of the production frontier coupled with the actual input-output combinations of firms is sufficient information for measuring efficiency. However, a major difficulty arises when estimating the production frontier since empirical production functions are 'average' rather than frontier functions, and therefore incapable of providing information on efficiency, since they attribute variations from the estimated function to symmetric random disturbances.

Farrell (1957:253-290) is one of the earliest researchers to use and measure efficiency and did this by comparing the firm's observed and optimal values of outputs and inputs. Farrell (1957) actually extended the works of Debreu (1951) and Koopmans (1951) who earlier on had began discussions on productivity and efficiency measurements in economic literature. Farrell demonstrated efficiency measurement using the input oriented approach where a firm was using two inputs, namely, capital (K) and labour (L) to produce output (Y). Farrell's works on efficiency measurements are illustrated in Figure 3 below. He assumed a firm producing a single output (Q) from two inputs (K, L).under constant returns to scale (CRS), and prior knowledge of an efficient production function. This was represented in diagrammatic form as shown in Figure 3. With the assumption of CRS, SS' represents an isoquant of various inputs combinations that are used in the production of one unit of output. The point P represents inputs combination (K, L) used in the production of a unit of output. Point Q represents an efficient input combination which is in the same

factor ratio as P. Thus, for the firm operating at point P, $TE = OQ/OP$. Similarly, if the price ratio is defined by the line AA', then $AE = OR/OQ$. The distance RQ represents a reduction in the cost of production that would occur if production was done in an allocatively efficient technique. The firm's economic efficiency is the product of TE and AE given by OR/OP. Therefore, this is the simplest way of determining a firm's efficiency based on the assumption that there is constant returns to scale and that the factors of production of a unit isoquant are well known.

Figure 3: Measurement of TE, AE and EE from a two input case isoquant under CRS

The two main categories of efficiency measurements that have been discussed in literature include the average production functions and the frontier approach. The former approach measures efficiency by first construing average productivity of inputs and then constructing an efficiency index. This method was deemed unsatisfactory by most economists as such functions were incapable of providing information on efficiency because they attributed differences from the estimated function to symmetric random disturbances (Pitt & Lee, 1981:44). Moreover, such functions are seen as average functions because they estimate the mean and not the maximum output. With so many flaws in this method, it led to the development of a new method which had better and well founded conceptual basis for measuring efficiency- the frontier approach (Aigner, *et al.* (1977); and Meeusen and van den Broeck (1977). To date this is the method which has

been widely used. The frontier approach to efficiency measurement can be divided into parametric and non-parametric. The non parametric approach describes frontier models which are robust with respect to the particular functional form and distribution assumptions, and is usually deterministic in nature. Deterministic production frontier models are those with output which is bounded from above by a non stochastic frontier. Such frontiers have a major flaw of not accounting for the possible influence of measurement errors and other statistical noise upon the shape and positioning of the estimated frontier.

The parametric frontier approach involves specification of a functional form for the production technology as well as making assumptions about the distribution of the error terms (Aye, 2010:52). In comparison to the non-parametric approach, the parametric approach has an advantage owing to its ability to express frontier technology in simple mathematical form as well as the ability to encompass non-constant returns to scale. The major flaw of the parametric approach is that sometimes unwarranted functional/structures may be imposed on the frontier. And when this is the case, it imposes a limitation on the number of observations that can be technically efficient. The parametric approach is divided into deterministic and stochastic frontiers. The parametric deterministic approach is further divided into the statistical and [1]non-statistical methods.

3.2.2 Theory underlying the frontier approach to efficiency measurement

One of the assumptions of the neoclassical economics is that firms are fully efficient in the production process (Kirsten *et al.*, 2006:10). The neoclassical economists assume that all firms are fully efficient in resource use in any production process and regardless of the sector they operate in. This however is contrary to the reality where all firms are seen to be hardly fully efficient in their production process (Kumbhakar *et al.,* 2006:72). Thus efficiency studies have shown contrast with the neoclassical view which assumes every firm to be fully efficient, when actually two or more indistinguishable firms cannot possibly produce the equivalent output since their quantity produced, expenses and revenue are

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[1] For details on Deterministic non-statistical frontiers, see Farrel (1957), and Aigner and Chu (1968).

different (Kumbhakar *et al.,* 2006:72). Therefore, in economics and other fields, the justification for the extensive utilisation of efficiency analysis is that firms are hardly totally efficient during production of goods and services (Kumbhakar *et al.,* 2006:73).

3.2.3 <u>Background to efficiency studies</u>

Several scholars have conducted efficiency studies using stochastic frontier approach. Some of these works which are related to the current study include Battese and Coelli (1988:387-399); (1992:153-169); (1995:325-332); Battese and Corra (1977:169-179); Bauer (1990:39-56); Coelli (1995:247-268); and Meeusen and van den Broeck (1977:435-444). Others include Pitt and Lee (1981:43-64); Hughes (1980:203-214); and Kumbhakar, Efthymios &Tsionas (2006:71-96); (2008:99-108). The most significant ones to the study are those by Battese and Coelli (1988:387-399); (1992:153-169); (1995:325-332); Battese and Corra (1977:169-179); Pitt and Lee (1981:43-64); Hughes (1988:203-214); and Kumbhakar, Efthymios &Tsionas (2006:71-96); (2008:99-108).

Although the field of production economics has been extensively studied, it was the pioneering works of Farrell (1957) which led to serious considerations of the possibility of estimating frontier production functions with a view of harmonising and bridging a gap between theory and empirical works (Aigner, *et al.*, 1977:21). However, Farrell's works only resulted in the estimation of average production functions (Aigner, *et al.*, 1977:21). One major flaw of average functions was that they are incapable of providing information on efficiency because they attributed differences from the estimated function to symmetric random disturbances (Pitt & Lee, 1981:44). Other efforts to estimate frontier production functions were done by Aigner and Chu (1968); Afriat (1972); Richmond (1974) and Pitt & Lee, (1981). Thus, Farrell (1957), Aigner and Chu (1968), Afriat (1972) and Richmond (1974) all estimated their frontier using linear and quadratic programming techniques. The initial proposed model was of the form:

$$y_i = f(x_i; \beta) \qquad\qquad 3.1$$

Where; y_i is the maximum possible output obtainable from x_i

x_i is a non stochastic vector of inputs, and

β is the unknown vector of parameters to be estimated

Thus, equation (1) postulates that for a given i^{th} firm the maximum possible output is a function of input vectors. Through the application of appropriate mathematical programming techniques based on a cross sectional sample, Aigner and Chu (1968) suggested the estimation of the β parameters through the minimisation of

$$\sum_{i=1}^{n}\left[y_i - f\left(x_i;\ \beta\right)\right] \tag{3.2}$$

Subject to;

$$y_i \leq f(x_i; \beta)$$

If $f\left(X_i;\ \beta\right)$ is linear in β, and

$$\sum_{i=1}^{n}[\boldsymbol{y}_i - \boldsymbol{f}\left(\boldsymbol{x}_i;\ \boldsymbol{\beta}\right)]^2 \tag{3.3}$$

Subject to;

$$y_i \leq f\left(x_i; \beta\right) \tag{3.4}$$

Which is a quadratic programming problem if $f\left(x_i;\ \beta\right)$ is also linear in β. However, their approach to frontier estimation could not succeed because the method did not allow for random shocks in the production process, which are outside the firm's control. As a result, maximum possible output determined from a given input was exaggerated because the frontier was determined only from a few extreme measured observations as the approach was extremely sensitive to outliers (Pitt & Lee, 1981:44).

Attempts to correct the flaws in Farrell's model were made by Timmer (1971) who eliminated a certain percentage of the total observations (Pitt & Lee, 1981). However, the selection procedure used by Timmer (1971) on the percentage of the total observations to be eliminated was arbitrary and that was not based on statistical theory (Pitt & Lee, 1981).

3.2.4 Stochastic frontiers and efficiency measurement

Stochastic frontiers come out as advanced type of the average and deterministic frontiers. Whereas deterministic frontiers attribute all variations in firm performance to variations in firm efficiency (which overlooks the fact that firm's efficiency may be affected by factors which the firm has no control of such as natural calamities, inflation rates, market failure, etcetera), SF takes these factors into consideration. The general stochastic frontier production function was proposed by Aigner, Lovell and Schmidt (1977:21-37), and Meeusen and van den Broeck (1977:435-444). They independently proposed the stochastic frontier production function, and ever since there has been considerable research and studies that have been conducted to extend and apply the model (Battese & Coelli, 1995:325). Aigner, *et al.* (1977), and Meeusen and van den Broeck (1977) recognised and solved the problems that were observed in the Farrell (1957), Aigner and Chu (1968), Afriat (1972) and Richmond (1974). They did this using a more satisfactory conceptual basis through the inclusion of an efficiency component in the error term of the estimated production function (Meeusen & van den Broeck, 1977:436). Thus, their model was represented as;

$$y_i = f(x_i; \beta) + \varepsilon_i \qquad\qquad 3.5$$

Where;

$$\varepsilon_i = v_i - u_i \qquad\qquad 3.6$$

ε_i is the disturbance or error term, the vector v_i are random variables which are assumed to be normally, identically and independently distributed between mean zero and variance σ^2 i.e. $v_i \sim NiiD\,(0, \sigma_v^2)$, while vector u_i is the error component which is assumed to be distributed independent of v_i, and that u_i are non-negative random variables (truncated at zero from below) which are assumed to account for the technical inefficiency in production such that $u_i \sim NiiD\,(0, \sigma_u^2)$.

Thus, based on the distribution assumption of the disturbance term, equation (3.5) above can be estimated using the maximum likelihood technique (Aigner, *et al.*, 1977). Equation

(3.5) is referred to as the stochastic frontier production function. As observed by Battese and Coelli (1995), the stochastic frontier production function postulates the existence of technical inefficiencies in production for firms involved in producing a particular output. Therefore, frontier functions provide the basis for defining efficient performance as their primary goal is to search for evidence of inefficiency (Reifschneider & Stevenson, 1991:1). That is, with the stochastic frontier production function, input use efficiency among smallholder farmers may be determined and based on the results a course of action can be sought to assist in ensuring that such inefficiencies are addressed (Battese & Coelli, 1995).

As equally noted by Bauer (1990:45), the use of frontier model has become increasingly widespread for the reasons being that: frontier is consistent with the underlying theory of optimising behaviour, and that deviations from a frontier have a natural interpretation as a measure of the efficiency with which economic units pursue their technical and behavioural objective. Bauer (1990:46) further attributed the increasingly widespread use of frontier models to the fact that information about the structure of the frontier and about the relative efficiency of economic units has many policy applications.

The concept of Stochastic Frontier Analysis employs maximum likelihood[2] method to estimate parameters which are used in efficiency analysis. From a given data set, and using a likelihood function, production frontier is estimated and the parameter estimates are derived from the normal equations obtained by partial derivatives of the logarithm of the likelihood function (Battese & Corra, 1977:169-172). The SFA approach is preferred for this study for the reasons stated above[3]. The variance parameters estimated using maximum likelihood and are used in efficiency analysis are;

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[2] According to Coelli *et al.* 2005, the concept of maximum likelihood is underpinned by the idea that a particular sample of observations is more likely to have been generated from some distributions other than from others, which also implies that the maximum likelihood estimates of unknown parameter are defined to be the value of the parameter that maximises the likelihood of randomly drawing a particular sample of estimations.

[3] For details on SFA see Battese & Corra (1977), Battese and Coelli (1988, 1992, 1995) and Coelli *et al.* (2005)

$$\sigma^2 = \sigma_u^2 + \sigma_v^2, \ \gamma = \frac{\sigma_u^2}{\sigma^2} \text{ and } 0 \leq \gamma \leq 1. \hspace{3cm} 3.7$$

If $\gamma \to 0 \Rightarrow \sigma_u^2 \to 0$ and $\sigma_v^2 \to \sigma^2$. This implies that the symmetric error term v_i predominates the composed error term, and the farm output differs from the frontier output mainly due to measurement errors and other external factors on production. If on the other hand $\gamma \to 1 \Rightarrow \sigma_v^2 \to 0$ and $\sigma_u^2 \to \sigma^2$. This indicates that the asymmetric non- negative error term u_i is predominant error in the composed error and the differences between the farm output and frontier output can be attributed to differences in technical efficiency. Technical efficiency in this case is measured as:

$$TE = E(e^{u_i}/u_i) = \left\{\frac{1 - \Phi[\sigma_i^* - (\mu_i^*/\sigma_i^*)]}{1 - \Phi(-\mu_i^*/\sigma_i^*)}\right\} e^{\left(-\mu_i^* + \frac{1}{2}\sigma_i^{*2}\right)} \hspace{2cm} 3.8$$

Where,

$\mu_i^* = \frac{\mu\sigma_v^2 - u_i\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$, $\sigma_i^{*2} \equiv \frac{\sigma_u^2\sigma_v^2}{\sigma_u^2 + \sigma_v^2}$ and $\Phi(-\mu_i^*/\sigma_i^*)$ or $\Phi[\sigma_i^* - (\mu_i^*/\sigma_i^*)]$ represents the cumulative distribution function.

The mean technical efficiency in this case is given by

$$\overline{TE} = E(e^{u_i}/u_i) = \left\{\frac{1 - \Phi[\sigma^* - (\mu^*/\sigma^*)]}{1 - \Phi(-\mu^*/\sigma^*)}\right\} e^{\left(-\mu^* + \frac{1}{2}\sigma^{*2}\right)} \hspace{2cm} 3.9$$

3.2.5 <u>Duality considerations in efficiency analysis</u>

Duality is the concept which is used in cost and profit functions. This concept is normally used especially in production economics mostly in cases where it is not possible to estimate cost functions because inputs among firms do not vary resulting in symmetric deviations from cost-minimising behaviour in an industry (Aye, 2010). Using a production frontier, it is possible to change the signs of the inefficient error component of the SFPF to a stochastic cost frontier model. The resulting dual cost frontier model will be of the form:

$$c_i = c_i(w_i, y_i, \delta)exp(v_i + u_i) \qquad\qquad 3.10$$

Where, c is the minimum cost of the ith firm, $c_i(w_i, y_i, \delta)exp(v_i + u_i)$, is the stochastic cost frontier, w_i is the vector of input prices of the ith firm, y_i is the output of the ith firm and δ is a vector of unknown parameters which are functions of parameters in the production function. The vector v_i are random variables which are assumed to be normally, identically and independently distributed between mean zero and variance σ^2 i.e. $v_i \sim NiiD\ (0, \sigma_v^2)$, and independent of u_i which are non-negative random variables assumed to account for the cost of inefficiency in production. In other words, u_i defines how far a firm operates above the cost frontier, and if AE is assumed it represents the cost of technical efficiency. When no AE assumption is made u_i has a vague interpretation.

Three main reasons are forwarded to justify use of alternative dual forms of production technology according to Coelli (1995b). The first reason is that dual forms reflect alternative behavioural objectives like cost minimisation, while the second reason is to accounts for multiple outputs. The third reason is to simultaneously predict both technical and allocative efficiency. Further, the decision to estimate either production or cost frontier lies in exogeneity assumptions. For instance, Schmidt (1986) suggested estimation of a production frontier whenever inputs are exogenous and a cost frontier in case of output being exogenous. A ML method for estimating a CD cost frontier with (k-1) factor demand equations was suggested by Schmidt and Lovell (1979). This system of equations was specified as:

$$lny_i = A + \sum \propto_i lnx_{ij} + v_i - u_i \qquad\qquad 3.11$$

$$lnx_{i1} - lnx_{ij} = lnp_{ij} - lnp_{i1} - ln \propto_1 - ln \propto_j + \varepsilon_{ij} \qquad\qquad 3.12$$

$$lnc_i = k + \frac{1}{r}lny_i + \sum_{j=1}^{k}\frac{\propto_j}{r}lnp_{ij} - \frac{1}{r}(v_i\text{-}u_i) + (E_i - ln\ r) \qquad\qquad 3.13$$

Equation 3.13 is the production frontier, while equation 3.14 is a set of first order conditions for cost minimisation, and 3.15 is the cost function. y_i is the output of the ith firm,

$x's$ are inputs, $p's$ are input prices and ε_{ij} represents allocative efficiency. $r = \sum_{j=1}^{k} \propto$ is the returns to scale. E_i is given as a function of ε's and the parameters. Now, the cost of technical inefficiency is given as $\frac{1}{r}u_i$, while the cost of AE is$(E_i - \ln r)$.

$$E_i = \sum_{j=2}^{k} \frac{\propto_j}{r} ln\varepsilon_{ij} + ln\left[\alpha_1 + \sum_{j=2}^{n} \alpha_j e^{-\varepsilon_{ij}}\right] \qquad 3.14$$

Schmidt and Lovell (1979) identified two major flaws associated with this approach. The first flaw is that it is usually not easy to estimate a cost frontier due to uniform input prices for firms in the same industry. The second reason is that this approach is only applicable to self dual functional forms such as the Cobb-Douglas, and do not apply to other functional forms like the translog.

3.2.6 **Efficiency decomposition**

Given production frontiers which exhibit self-dual characteristics such as the Cobb-Douglas production frontier, it becomes easy to understand the behaviour of its alternative form. For instance, from a production frontier only technical efficiency of a firm can be obtained while allocative and economic efficiency can only be obtained if and only if the given frontier is self dual. Thus, assuming a logarithmic self dual CD production frontier of the form:

$$lny_i = A + \beta_i lnx_i + \varepsilon_i \qquad 3.15$$

Where $A = ln\beta_0$, y_i, x_i and the parameters β_i, are already defined above. Further, the composed error term (ε_i) is obtained by subtracting predicted output from observed output such that:

$$\varepsilon_i = y_i - \hat{y_i} \qquad 3.16$$

Using the maximum likelihood method parameters of the stochastic frontier production function are estimated, and by subtracting v_i from both sides of equation (3.15), get;

$$y_i^* = y_i - v_i = A + \beta_i ln x_i - u_i \qquad\qquad 3.17$$

Where y_i^* is the observed output of the ith firm adjusted for statistical noise captured by v_i. Using equation (3.17), technically efficient input vector x_i^T for a given level of y_i^* is obtained by solving simultaneously equation (3.17) and the input ratios, $x_i/x_k = p_k (k > 1)$ where p_k is the observed inputs ratio. With the duality assumption, the corresponding dual cost frontier is expressed as:

$$c_i = h(w_i, y_i^*, \delta) \qquad\qquad 3.18$$

Where c_i is the minimum cost of the ith firm associated with output y_i^*, w_i is a vector of input prices of the ith firm, and δ is a vector of parameters which are assumed to be functions of parameters in the production function. Further, using shepherds' lemma, the economically efficient (cost minimising) input vector x_e is obtained by substituting the firms input prices and adjusted output quantities into the system of demand equations:

$$\frac{\delta c}{\delta w_i} = x_{ij} = x(w_i, y_i^*, \delta) \qquad\qquad 3.19$$

Hence, from the given technically and economically efficient input packages the actual cost of observed input levels by their respective prices as $w_t * x_t$ in the case of *technical efficiency* (TE) and $w_e * x_e$ in the case of *economic efficiency* (EE) can be calculated. Thus

$$TE = \frac{(W_t * X_t)}{\sum(W_t * X_t)} \qquad\qquad 3.20$$

And similarly,

$$EE = \frac{(W_e * X_e)}{\sum(W_e * X_e)} \qquad\qquad 3.21$$

Since $EE = TE * AE$, it means that $AE = \frac{EE}{TE}$

$$\sim 40 \sim$$

Therefore,

$$AE = \left[\frac{(W_e * X_e)}{\sum(W_e * X_e)}\right] / \left[\frac{(W_t * X_t)}{\sum(W_t * X_t t)}\right] \qquad 3.22$$

However, this functional form is associated with limitations among which are that RTS for all firms take the same value and that elasticity of substitution is assumed to be equal to one.

3.3 EMPIRICAL LITERATURE

3.3.1 <u>Empirical comparative studies</u>

Several efficiency studies have been conducted by several researchers world over while using different techniques. This section gives the findings of a few selected studies that relate to the study. Battese and Coelli (1995:325-332), in their study of Technical Inefficiency Effects in a Stochastic Frontier Production Function using panel data concluded that the inefficiency effects were stochastic and depended on the farmer-specific variables as well as the time of observation. Farmer-specific variables herein refer to inputs used in the production process such as labour and capital which are associated to each firm. They used a linearised version of the logarithm of Cobb-Douglas production function where different input variables accounted for different effects. For instance, they used age, schooling, years in production, etcetera, to account for technical change and time varying effects. They further obtained their maximum likelihood estimates of the parameters of the model using a computer programme, FRONTIER 2.0.

Similarly, Battese and Coelli (1992:153-169) effectively demonstrated the importance of frontier production function in predicting technical inefficiency of individual firms in an industry. They demonstrated this using panel data for which firm effects were an exponential function of time, and concluded that technical inefficiencies of the farmers were not time invariant when the year of observation was excluded from the stochastic

frontier. The opposite was true when year of observation was included in the stochastic frontier.

Comparisons have also been made between the traditional (average) Cobb-Douglas function and the generalised frontier model and the results have shown that generalised frontier models are more suitable models in the study of technical inefficiencies. For example, a study by Battese and Coelli (1988:387-399) on the prediction of firm level technical efficiencies revealed that the traditional Cobb-Douglas production function was not a suitable model for prediction. They applied a stochastic frontier production function to the dairy industry of New South Wales and Victoria. They further observed that a more generalised model for describing firm effects in frontier production functions accounted for the situations in which there was high probability of firms not being in the neighbourhood of full technical efficiency.

Using a time series of cross-section data on Indonesian weaving establishments, Pitt and Lee (1981:43-64) estimated a production function from which sources of technical inefficiency were investigated. They identified ownership, age and size as being the attributes that were firm efficiency. A method of maximum likelihood was used to obtain estimates for the model with time invariant efficiency component and the mean efficiency for the weaving industry was determined.

However, efficiency analysis differs depending on whether one uses the Input oriented or output oriented approach in the measure. For example, the study by Kumbhakar, Efthymios and Tsionas (2008:99-108), on estimation of input-oriented technical efficiency using a non-homogeneous stochastic production frontier model, and using the both the input oriented (IO) and the output oriented (OO) technical revealed differences in the results obtained. Kumbhakar, *et al.* (2008:99-108) demonstrated this using same sample of 80 Spanish dairy data from 1993–1998, and with the same data; they estimated a simple non-homogeneous SFPF with IO technical efficiency and showed that the estimated technology differed depending on whether one uses the IO or OO formulation. They specifically computed returns to scale and technical efficiency levels from both the IO and the OO models and compared the results. Apart from this, they obtained observation-

specific estimates of IO and OO technical inefficiency and expressed them in common units for a direct comparison and interpretation of efficiency results. This was done because the interpretations of IO and OO technical inefficiency are different. The empirical result confirmed the theoretical result that the IO and OO models are exactly the same on under constant returns to scale.

A study by Kumbhakar *et al.* (2006:71-96) also demonstrated the differences in the results obtained from these two different models. That is, they used a simulated ML approach to estimate the IO production function and compared results from the IO and OO models; mainly to emphasize the point that estimated efficiency, returns to scale and technical change, differ depending on whether one uses the model with IO or OO technical inefficiency.

Bravo-ureta and Pinheiro, (1997), analysed technical, economic, and allocative efficiency in peasant farming: evidence from the Dominican Republic. They used Maximum likelihood techniques to estimate a Cobb-Douglas production frontier which was then used to derive its corresponding dual cost frontier. These two frontiers formed the basis for deriving farm-level efficiency measures. The results of their study revealed average levels of technical, allocative, and economic efficiency of 70 per cent, 44 per cent, and 31 per cent, respectively. These results suggest that substantial gains in output and/or decreases in cost could be attained given existing technology. The results also point to the importance of examining not only *TE*, but also *AE* and *EE* when measuring productivity. In their second stage regression where they used Tobit to regress *TE*, *AE*, and *EE*, on various socio-economic attributes of the farm and farmer (contract farming, agrarian reform status, farm size, schooling, producer's age, and household size), the results showed that younger, more educated farmers exhibited higher levels of *TE, AE* and *EE* their older counterparts. Additionally, the study also showed that that contract farming, medium-size farms, and being an agrarian reform beneficiary had a statistically positive association with *EE* and *AE*. On the contrary, the study also revealed that the number of people in the household had a negative association with *AE.* In conclusion, the researchers observed that for the peasant farmers in the Dominican Republic *AE* appeared to be more significant than *TE* as a source of gains in *EE* which from the policy

point of view, contract production, farm size, and agrarian reform status were the variables found to be most promising for action.

3.3.2 <u>Comparative empirical studies applied to the African agricultural sector</u>

Arega (2003) assessed the impact of new maize production technology and efficiency of smallholder farmers in Ethiopia using the stochastic efficiency decomposition technique to analyse technical, allocative and economic efficiency of farmers in different agro-climatic zones. Although the study revealed positive result for improved production technology and production efficiency, inefficiencies were observed under both the traditional and improved method. That is, the study revealed production efficiency under the traditional maize production as being attributed to technical inefficiency while inefficiency under the improved system was as a result of both technical and allocative efficiencies. The implication of this was that both technical and allocative efficiencies needed to be raised to under the improved technology.

Debela, Heshmati and Oygard (n.d) evaluated the impacts of economic reform on performance of agriculture in Ethiopia. They used a sample of small farms located in the two peasant associations (administrative units) of the Ada-Liben district of the central highlands of Ethiopia. The sample survey was conducted at two separate intervals: in 1993/94 and 2000/01 agriculture seasons. The data sets covered the same 80 households observed during both survey years, 40 households were randomly selected in 1993/94 from each of the two peasant associations using a standard survey questionnaire.

They used a Cobb-Douglass (C-D) functional form to specify the stochastic frontier production function and based on its duality characteristics they derived a cost frontier. The two SFPF provided the basis for measuring efficiency. The justified the use of this function of the fact that in as much as the CD production function imposes restrictions on the structure of the technology, methodology employed required that the production function be self-dual. They moreover noted that this functional form has been widely used in farm efficiency analysis because of the ease with which it is interpreted and that it holds the promise of more statistically efficient parameter estimates (Liu and Zhuang, 2000: *In*

Debela, *et al.*, (n.d)). They also noted that since their model has a large number of inputs, by using a simple functional form, the risk of multicollinearity due to addition of interactions and square of the input variables could be avoided.

The results of their study showed that *TE* tends to increase little over time though it was statistically insignificant. Average *AE* and *EE* had on the other hand declined over time while their minimum values had slightly increased over the same period. Maximum economic efficiency has declined over the period while maximum allocative efficiency increased slightly. This indicates that for most of the farmers, economic efficiency including the most efficient farmers in the first year, have declined. Similar argument for allocative efficiency is that while most inefficient and most efficient farmers have improved efficiency, allocative efficiency has deteriorated for most of the farmers in the sample.

The results indicate that there is evidence of significant technical and allocative inefficiencies among the farmers. From the findings, there is no evidence that policy reforms have improved technical efficiency in production over the period significantly. On the other hand allocative and economic efficiency have deteriorated over the period. The policy implications of the study were that if the cycle of poverty and famine were to be broken there was need to formulate policies that would target both the supply and demand-side factors of agricultural productivity growth

Tchale (2009) studied the efficiency of smallholder agriculture in Malawi using a nationally representative sample survey of rural households undertaken by the National Statistical Office in 2004/2005. The aim of the study was to inform agricultural policy about the level and key determinants of inefficiency in the smallholder farming system that need to be addressed to raise productivity. The researcher used a parametric frontier approach because of the many variations that underlie smallholder production in developing countries. This was so because the stochastic frontier attributes part of the deviation to random errors (reflecting measurement errors and statistical noise) and farm specific inefficiency (Forsund et al., 1980; Battese & Coelli, 1995; Coelli *et al.*, 1998).

The results revealed that allocative or cost inefficiency is higher than technical inefficiency, and that the low economic efficiency level could largely be explained by the low level of allocative efficiency relative to technical efficiency. High levels of cost inefficiency were probably attributable to the low profitability that resulted from inadequate agricultural market development. Thus improvement of efficiency hinges largely on improving the policy and institutional environment so that farmers' net profitability will be enhanced. More importantly, efforts must be made to promote private market development.

In the two stage regression access to markets and access to extension services (especially which related to crop production; and the use of fertilizer and improved seed varieties) were the significant determinants of farm level efficiency. The conclusion of the study was that in Malawi the small maize farms are more efficient than the large ones. The study also found that the factors that improve efficiency are higher output prices relative to input costs, favourable commodity and input markets, farmers' organizations, extension, productive assets, and the quantity and productivity of household labour. The wide range of inefficient practices suggested that there is considerable scope for improving efficiency in the smallholder sub-sector. The policy implications of the study were that there was need to revamp productivity of smallholder agriculture and to this requires a sustained effort to improve farmers' access to technological information and product markets and to lower the risks they face.

3.4 EMPIRICAL MODELS FOR THE STUDY

There are various methods which are available for use in efficiency analysis. These include the parametric and the non-parametric approaches. The choice between these approaches has been a contentious issue with some researchers preferring the parametric approach to the non-parametric approach while others preferring the non-parametric approach to the parametric. In this study, the parametric approach is utilised in the estimation of the single output production technology to estimate a production frontier which traces out the maximum feasible maize output for different input levels.

Two models were used for this study; these are the translog and the Cobb-Douglas parametric stochastic frontier production functions. The two models were applied on the same sample beginning with the translog and then the CD. The reason for this was to facilitate comparison of results from the two models given the fact that each of these has its own pros and cons with regard to the empirical performance.

The translog functional form is deemed computationally flexible, imposes no restrictions on RTS and assumes no elasticity of substitution. The actual translog analytical model was adopted from Wadud (2003), expressed as:

$$lnY_i = \beta_0 + \sum_{k=1}^{K}\beta_k ln(X_{ki}) + \frac{1}{2}\sum_{k=1}^{K}\sum_{j=1}^{K}\beta_{kj}ln(X_{ki})ln(X_{ji}) + (v_i - u_i)$$ 3.23

Where; Y_i represents the value of maize output, X_{ji} are inputs land, labour, fertiliser and seed and ln indicates the natural logarithms. However, the coefficients of the translog stochastic frontier do not have a straight forward interpretation as the output elasticities with respect to each of the inputs are functions of the first and second order coefficients (Alvarez & Gonzalez (1999:8), Nchale (2007:20), Onumah & Acquah (2010:829) Wadud (2003:117) and Zhang & Xue (2005:25)). Partial elasticities of output with respect to inputs are estimated because they permit the evaluation of the effect of changes in the amount of an input on the output. The partial elasticities for each input are estimated using the equation:

$$\frac{\partial lnE(y_i)}{\partial lnx_{ji}} = \{\beta_j + \beta_{jj}lnx_{ji} + \sum_{k=j}\beta_{jk}lnx_{ki}\} - c_{ji}\left\{\frac{\partial\mu_i}{\partial x_{ji}}\right\}$$ 3.24

Where,

$$c_i = 1 - \frac{1}{\sigma}\left\{\frac{\phi(\mu_i/\sigma-\sigma)}{\Phi(\mu_i/\sigma-\sigma)} - \frac{\phi(\mu_i/\sigma)}{\Phi(\mu_i/\sigma)}\right\}$$ 3.25

The first part of equation 3.22 is referred to as the elasticity of frontier output while the second part is called the elasticity of technical efficiency. The second part is zero in frontiers model (see Battese & Coelli (1995) for details), which means that the elasticities

for the inputs land, labour, fertiliser and seed are independent of the elasticities of technical efficiency. The elasticities obtained using equation (3.22) now interpretable.

The CD analytical model on the other hand was derived Bravo-Ureta and Rieger in Bravo-Ureta and Pinheiro (1997) specified as:

$$lnY_i = \propto + \sum_{j=1}^{4} \beta_j lnX_{ji} + v_i - u_i$$

3.26

Where $\propto$ and β_i, are parameters to be estimated. Using equation 3.18 above, the corresponding Cobb-Douglas dual cost frontier was derived using vectors of input prices for the ith farm (W_{ji}), the SFPF (β_j) of equation 3.26 and the input oriented adjusted output level of Y_i^* are known. Thus the corresponding CD dual cost frontier is;

$$lnC_i = b_o + \sum_{j=1}^{4} b_j lnW_{ji} + \emptyset lnY_i^*$$

3.27

Where,

$$\emptyset = \left(\sum_{j=1}^{4} \widehat{\beta_J}\right)^{-1}, b_j = \emptyset\widehat{\beta_j} \text{ and } b_o = \frac{1}{\emptyset}\left(\widehat{\beta_0}\prod\widehat{\beta_J}^{\widehat{\beta_J}}\right)^{-\emptyset}$$

Using shepherd's lemma, X_i^c which is the economically efficient input vector, is derived by substituting the firm's input prices and the adjusted output quantities into a system of compensated demand equations expressed as:

$$\frac{\partial C_i}{\partial W_i} = X_i^c = b_j W_j^{-1} Y_i^*$$

3.28

Hence, for a given level of output, TE, EE and the actual cost of production are equal to $W_i X_i^T$, $W_i X_i^c$ and $W_i X_i$, respectively. These three cost measures form the basis for calculating TE and EE for the ith firm. Therefore,

$$TE_i = \frac{W_i X_i^T}{W_i X_i}$$

3.29

and

$$EE_i = \frac{W_i X_i^c}{W_i X_i}$$

3.30

Since $EE = TE * AE$, it means $AE = \frac{EE}{TE}$ which is:

$$AE = \frac{W_i X_i^c}{W_i X_i^T}$$

3.31

Two approaches are used in the estimation of efficiency models. These are the *one step* and the *two step* procedure. Efficiency estimation in the one step procedure estimates all parameters in just one step where inefficiency effects are defined as a function of the firm's specific factors but are incorporated directly in the maximum likelihood estimation. In other words, both the frontier model and the efficiency models are simultaneously estimated. In the two step procedure, the PF is first derived after which TE of each firm is derived. The TE estimated are then regressed against a set of variables which are hypothesised to influence the firms' efficiency. The two step procedure was proposed by Battese and Coelli (1995), in their model for measuring technical inefficiency effects in SFPF for Panel Data. This model showed that technical inefficiency effects, u_i, is obtained by truncation (at zero) of the normal distribution with mean, $\mu_{i,}$ and variance, σ_u^2 such that:

$$u_i = Z_i \delta + \varepsilon,$$ 3.32

Where, *Z* is a vector of farm-specific explanatory variables, and δ is a vector of unknown coefficients of the farm-specific inefficiency variables.

Among the advantages of SF models are that they control for random unobserved heterogeneity among firms, the statistical significance of variables determining efficiency can be verified using statistical tests and that the firm specific inefficiency is not measured in relation to the best performing firm as it is done in non-parametric approaches. The main disadvantages are that in SF there is need to make distributional assumptions for the two components plus the independence assumptions between the regressors and the error term.

The models were estimated using FRONTIER v4.1 which generated ML parameter estimates and also gave the individual household's technical efficiency figures. Both Economic efficiencies and allocative efficiencies for the individual smallholder households were estimated using STATA v8.0.

3.5 CONCLUSION

In conclusion, literature reviewed thus far has shown the importance of conducting efficiency analysis in determining farm level efficiency. The papers reviewed are dated as far back as 1957 and as recent as 2010. In all these papers what has been apparent is that for a group of smallholder farmers it is extremely important to identify the sources of their inefficiency as well as the major determinants of such inefficiencies so as to recommend the most appropriate policy to address such problems. Therefore, in addition to enriching the researcher with knowledge on efficiency and various approaches to its measurement the researcher has also learnt a great deal from the related papers reviewed with regard to smallholder agriculture. This actually provides a rich background on the knowledge, experiences and other issues to look out for throughout this study. Additionally, based on the literature reviewed this study endeavoured to utilise the CD SFPF in deriving allocative and cost efficiency. The translog functional form was also modelled for the sake of comparing the structural properties to determine which one of the two best described the smallholder production data from Chongwe District. Based on the selected function efficiency analysis was conducted from which conclusions was made about the sample.

CHAPTER 4

RESEARCH AND INSTRUMENT DESIGN, SURVEY IMPLEMENTATION AND THE SOCIO-ECONOMIC CHARACTERISTICS OF THE SAMPLED HOUSEHOLDS

4.1   INTRODUCTION

The section that follows highlights the research and survey instrument design, survey implementation and the socio-economic characteristics of the sampled households as well as model summaries for the study. Section 4.2 discusses the survey instrument, implementation and broad research design. Section 4.3 presents data collection procedure with section 4.4 describing the main variables used in the study. Household characteristics of the sample are presented in section 4.5 while section 4.6 gives summarised versions of the models used in the study. The chapter will end with a conclusion in section 4.7.

4.2   SURVEY INSTRUMENT, IMPLEMENTATION AND BROAD RESEARCH DESIGN

Efficiency in production economics is a relative term that is measured through comparison of the actually realised result of an objective function with that attainable at the frontier. This means that for any given set of firms and using the input sets used in the production process, a frontier function can be derived against which each firm's efficiency can be measured. However, this poses a great challenge when dealing with firms which do not use inputs regularly and have poor record keeping like the practice of smallholder farmers in general. Among the many challenges lies the choice of a standard research instrument which is not only appropriate for the study but also contains best proxies that would accurately estimate and represent resources required in the production process with minimum measurement errors. Against this background and based on the characteristics of the target group, the most appropriate inquiry strategy was the survey research and modelling of primary data. According to Assefa (in Arega, 2003:67), surveys are useful

methods of research especially where the study involves collection of variables that can be measured and aggregated with minimum problems and errors. Thus, variables such as resource use, production data, cost and profits of a production process can be directly measured and quantified hence basic information for these factors can easily be obtained from a survey.

The specific approach used in the study was the stochastic frontier analysis during which both translog and Cobb-Douglas stochastic frontier production function were estimated and used in efficiency analysis. The SF approach is suitable for the study because such models contains a random variable which takes into account measurement errors and other sources of statistical noise other than those that are as a result of technical inefficiency (Coelli *et al.*, 2005:242).

4.3   DATA COLLECTION PROCEDURE

4.3.1   <u>Survey design and sample selection</u>

Conducting a census on every individual smallholder maize producer so as to determine the level of efficiency is the most accurate and desired way of approaching the study. However, this was not feasible because of limited financial resources and time limitation. Hence, the only possible alternative was to conduct a sample survey which is based on the laws of probability so as to ascertain accuracy of the results and be able to make reasonable inferences. The degree to which a sampling method is deemed appropriate depends on the extent to which it successfully meets the objectives of the study. With this in mind a combination of stratified random sampling coupled with purposive sampling in what was known as the multi-stage sampling was used in the study.

In the first instance, the country's three agro ecological zones acted as stratas of these, region II provided the most ideal climatic conditions for maize production. The other considerations involved purposive selection of the district based on support services (subsidised inputs and extension services) received, which made *Chongwe* the most ideal district. Therefore, the target population included all smallholder maize producers in

Chongwe district of Zambia from whom a representative sample was drawn, while the sampling unit was the household. Each district is subdivided into wards which are further subdivided into Census Supervisory Areas (CSA) and Standard Enumeration Areas (SEA) by Zambia's Central Statistical Office (CSO) for the purpose of sampling. The SEA is the smallest area containing approximately between 100-150 households. Thus, all smallholder households are organised into SEAs. The district has a total of 12 SEA with 1500 households who are actively participating in small-scale agriculture (CSO, 2010:6).

Determining the most appropriate sample size can be a rather tricky task to do. This is so because of the various factors which influence this determination. Although, this choice of sample size is theoretically determined by statistical formulas based on the laws of probability and the pre-assigned level of accuracy, factors such as scarce financial resources required to carry out the study as well as time limitation largely override this (Asefa, 1995:15). Hence, owing to these limitations sample sizes are usually small and are only equated to the available resources. Based on the aforementioned limitations, a sample consisting of 120 households was collected from the twelve SEAs

4.3.2 Data collection

Both primary and secondary data was used in this study. This data contained production related variables as well as the demographic and the socioeconomic characteristics of the sampled households.

Primary data was collected using a semi-structured and detailed questionnaire which was administered to a sample of smallholder households who were selected using both stratified and purposive sampling methods. The purpose of the questionnaire was to collect all relevant information regarding parameters that enter in the production of maize (which included both inputs used in the production process and the output obtained from those inputs), which was used to measure efficiency. The vital information collected included amount of fertiliser applied per unit area, sources and quantity of labour for production, other supplementary inputs in the production process, *etcetera*. Enumerators used in the study were sourced among MACO staff from the District for the reason being

that they have good understanding of the district as well as the smallholder household in the area. These were then trained on how to use the survey instrument, and they were actually taken through the whole question so as to give them a clear understanding. Prior to actual data collection, the questionnaire was pre-tested on a few respondents to check for the possible errors that could affect the quality and accuracy of data collected.

To address the first and second objectives, information on farmers' output and input quantities as well as prices were collected. Output for which quantities and prices were collected in this case was maize produced during the 2009/2010 agriculture season. The inputs for which quantities and prices were collected included land/area under cultivation, household labour as well as hired labour, inorganic fertiliser and maize seed. Moreover, to address the third and fourth objectives information of the households' socio-economic characteristics as collected. This included age, sex, education level, occupation, years in farming, land ownership, access to extension services and access to credit services.

Secondary data which acted as supplementary data was collected from the Ministry of Agriculture and Cooperatives and Central Statistical Office as these are the organisation that collects data annually from this group of farmers for statistics purposes. This data was used for comparisons sake as well as for the sake of augmenting information in the study. Other sources of secondary data were co-operatives and NGOs who work closely with the farmers.

The primary data collected was transcribed on to MS Excel spread sheets from which summary statistics were obtained using MS Excel for the purpose of verifying that there were no possible outliers that would have affected the results. The measures of central tendency like the mean, mode and median were used to this effect. Data coding and definition of variables was done using SPSS and EViews. Derivation of the stochastic frontier production functions as well as measurement of efficiency will be done using frontier v4.1 (Coelli, 1996), while a two-stage regression on efficiency scores on determinants was run using STATA.

4.4   VARIABLE DESCRIPTION

This section describes the main variables which were used in the analysis. The means and standard deviations of output and input variables used in the analysis are given. Land, labour, fertiliser and seed are the inputs which smallholder mainly use in crop production.

In the SF model, OUTPUT (y_i) referred to the quantity of maize produced by each household for the 2009/2010 agriculture season measured in kilograms. The LAND (l_i) input referred to the area which was cultivated for maize production by each smallholder household for the 2009/2010 agricultural season measured in hectares. LABOUR (la_i) was estimated as a summation of both household and hired labour measured in man-days which was used by individual households during the 2009/2010 agriculture season. FERTILISER (f_i) was the amount of inorganic fertiliser which was applied per hectare of land cultivated by each household for maize during the period under study. Amount of fertiliser applied was measured in kilograms. Fertiliser applied by each farm household was assumed to be the quantity that each farmer purchased and/or received during the season under study. SEED (s_i) refers to the quantity, in kilograms, of hybrid maize seed which each household planted per hectare of land during the 2009/2010 agriculture season.

Two methods were used when estimating area cultivated for maize. The first method was a physical field inspection where enumerators physically visited the area that had been used for maize production in the period under study. This method was mostly used in cases where households lived close to their fields. Using this method, enumerators estimated area under study by way of counting the number and length of lines planted with maize. By local conversion, 120 lines of length 100 metres were equivalent to one hectare. The second method which was actually used as a supplementary method involved extrapolating the quantity of seed planted as well as amount of inorganic fertiliser applied on an area. By this conversion if 20 kilograms of maize seed was planted or 400 kilograms of fertiliser applied then the area under cultivation was taken to be one hectare.

Table 3 shows the mean, standard deviation as well as the range (minimum and maximum) values for each variable use in the estimation of the SFPF.

Table 3: summary statistics for output and input variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Output				
Output (y_i)	2981.00	2248.00	800.00	9400.00
Land (l_i)	1.15	1.00	0.25	3.00
Labour (la_i)	131.7	78.00	14.00	451.00
Fertiliser (f_i)	390.00	289.00	100.00	1200.00
Seed (s_i)	20.42	13.00	10.00	50.00
Prices				
W$_{LAND}$	251111.56	32992.72	223428.25	317689.48
W$_{LABOUR}$	5659.23	2138.61	2177.07	8524.48
W$_{FERTILISER}$	4000.41	1661.89	2742.27	6650.08
W$_{SEED}$	36000.00	4766.02	34549.97	36602.72

Source: Author's own construct

Table 3 above shows that the mean quantity of maize harvested per household was 2981kg with a standard deviation of 2248. In addition to deriving the SF production functions for maize using these inputs, cost function was derived using the self dual properties of the CD as the input prices were also collected during the study. The prices for land (w_l) and labour (w_{la}) were obtained using their opportunity cost. Thus, the price for land (w_l) was estimated using the rental charge which was paid for a hectare of hired land cultivated by each household during the agriculture season. That is, the price for land was determined using the rental/lease charge that households who rented/leased land paid/received, respectively, per hectare of land. Similarly, labour cost was estimated using the amount an individual received/paid for hiring out/in labour for a day. Thus, the price for labour (w_{la}) per man-day was estimated using the amount paid to individuals on piece-works. Prices for maize (w_s) seed (per kilogram) and inorganic fertiliser (w_f) (per kilogram) were obtained by collecting secondary data on commodity market prices for the 2009/2010 agriculture season. Therefore, based on the above premise land cost was estimated at ZMK251111.56 per hectare and labour costed ZMK5659.236 per man-day. The market

value for fertiliser and seed were ZMK4000.41 per kilogram and 36000 per kilogram. The price details per unit as well as per standard pack are also shown in Table 3.

In addition to these, other variables which were used in the two-stage regression as the determinants of efficiency were also described. These include respondents' AGE, SEX (1-male, 2 female), EDUCATION LEVEL (number of years respondent spent in formal education which was either no education, primary or post primary), MAIN OCCUPATION (famer or non farmer), YEARS IN FARMING (categorised into five years or below and above five years), LAND OWNERSHIP (land size owned by a household in hectares), ACCESS TO EXTENSION (an indication of whether households received any visits from agriculture extension officers during the period under study), and ACCESS TO CREDIT SERVICES (indicating whether households used credit for farming inputs or not)

4.5   HOUSEHOLD CHARACTERISTICS OF THE SAMPLE

Throughout literature several farm and household characteristics have been shown to have an influence on farm level efficiency. For the purpose of this study the following characteristics were analysed: age, sex, education level, occupation, years spent in farming by a household, land ownership, household size, access to extension services and access to credit services. A total of 120 smallholder maize producers were sampled from Chongwe District, with the sample distribution being as shown in Table 4. As indicated in the table, more households were sampled from the most productive area of the district and the villages sampled from this area listed in Table 4. Villages from the less productive area of the district were aggregated into one group owing to the few households that were sampled from the individual villages. Of the 120 sampled households 74 households (or 61.7 percent) were female headed while 46 (38.3 percent) were male headed. This differs from the national census statistics 2000 where the ratio male to female was 49.88 percent to 50.12 percent. The possible reasons for this could be that the majority of households sampled were female headed and perhaps that it has been ten years since a national census was last conducted making it possible that the country's demographics might have changed. Hence, the observed disparities in sex distribution between results obtained from the study and that of national statistics of 2000. The average household size was 7.5.

Family size is very important since it determines the availability of household labour, which is essential during agriculture production season. Therefore the larger the household size, the better it is for a household to participate in maize production and minimise the cost of hiring labour.

Table 4: Household distribution by village

Village	Frequency	Percent
Bunga	24	20.0
Chiyalusha	27	22.5
Shamboshi	18	15.0
Shibale	24	20.0
[a4]Other	27	22.5
Total	**120**	**100.0**

Source: own survey data

The age attribute of the respondents was analysed with reference to Zambia's Central statistical office (CSO) which categorises age in the following groups: 0-14 years; 15-64 years, and 65 years and above. The minimum age of the respondents was 16 years old while the maximum age was 80 years old. The average age of respondents was 42.2 years old with a standard deviation of 13.29.

With regard to education attainment, the study showed that 27 (22.5 percent) of the respondents never attended any formal education, 72 (60 percent) of the respondent attained primary education, while 21 (17.5 percent) went up to [5]post primary (secondary and tertiary) education. In terms of literacy levels the study revealed that 77.5 percent (100-22.5 percent) of the respondents are literate, which in comparison with the figure obtained from the national statistics 2000 does not differ significantly. Further, results show that majority of households (60 percent) have only attained primary education which is equally the case with the national statistics which shows that majority of the population

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[4] The 'other' category include villages Kampekete, Kwale, Muteba, Mwakaule, Saiti and Sekelela which are located in the less productive area of the district.

[5] This category is an aggregation of secondary and tertiary education which had 15.8% and 1.7% of the respondents, respectively, and was deemed too small to be entered individually in to the regression.

above 15 years have attended primary school. The study also revealed that the main occupation of the 118 respondents (98.3 percent) is farming, while those who are civil servants and the self-employed were only 1.7 percent each. Categories for civil servant and self employed were aggregated into one group called 'other' for the sake of regression analysis where one would want to know whether one's occupation as an influence on the output.

Years spent in farming was another characteristic captured in the study as it is one of the most important variables which has a bearing on farmers' productivity and efficiency. In theory it is expected that the more number of years one spends in farming is the more productive and therefore more efficient their production process will be. In the study it was revealed that on average smallholder maize producers in the area under study had spent at least 15 years in farming. The number of years spent in farming by each household were categorised into two: 0-5 years and above five years. 98 (81.67 percent) of the households had only been farming for less than five years while 22 (18.33 percent) have been farming for more than five years.

Land forms one of the major assets used in farming by smallholder farmers in Chongwe district and the whole country at large. In general, land in Chongwe is grouped into land owned by the farmer, land rented from other households and land that are leased to other households for production. Note also from the earlier discussion in chapter one that smallholder farmers in Zambia are made up of small scale farmers who own land up to five hectares, and emergent farmers who own land between five and twenty hectares.

However, since for this category land is discussed as an asset and not as per area cultivated during the period under study, only statistics for land actually owned are shown. The average land owned by each household in the sampled population was 3.33 hectares with a standard deviation of 2.67. The minimum size of land owned is zero while the maximum is 14 hectares.

In Zambia, smallholder farmers are encouraged to belong to farmers organisations not only for the sake of sharing farming experiences but also as a way of raising resources

Table 5: Household characteristics of the sample

Variable / measurement	Mean/frequency	Standard deviation
Age	42.2	13.29
Sex		
Male	38.3	
Female	61.7	
Education level		
No education	22.5	
Primary education	60	
Post primary education	17.5	
Main occupation		
Farming	98.3	
Other	1.7	
Years in farming		
0-5 years	81.67	
Above 5 years	18.33	
Mean years spent	15.48	11.53
Land ownership		
0-5ha	79.17	
6-20ha	20.83	
Mean land owned	3.33	2.67
Access to extension services		
Yes	80.83	
No	19.17	
Access to credit services		
No access	64.16	
Access	15.84	
Own savings	20	

Source: *Author's own construct*

collectively which are used to acquire farming inputs. Moreover, these groups are used as a way of strengthening their voice to government and other private organisations which are involved in inputs supply and marketing of farm produce. However, not all farmers' organisations are as important to Zambia's smallholder farmers as the cooperatives are, because it is only farmers who belong to the cooperatives who access subsidised inputs and access extension services than those who do not belong to any organisation. What determines one's membership to these cooperative is dependent upon one's ability to pay membership fee. Thus, only smallholder households who belong to these cooperatives are the ones who manage to pay membership and other fees that the cooperative leadership determine based on the input prices for the agriculture season.

Thus in the study it was revealed that 97 (80.8 percent) of the sampled smallholder households belong to the farmers' cooperatives through which government offers subsidised inputs and therefore had access to extension services, while 23 (19.2 percent) of the total sampled households did not belong to cooperatives and therefore had no access to extension services

Credit source is equally an important factor that one has to consider when conducting research on smallholder farmers as it influences farm level efficiency. Although this attribute is not very common among smallholder farmers as they do not require such expensive and sophisticated equipments in their production, minimum capital is required for them to acquire inputs such as fertiliser and seed, pay up membership fees, and in some isolated instances use it to lease land for farming. Therefore, based on the fact that smallholder farmers require minimum credit to facilitate their production process, they were asked about their sources of credit for farming. The outcome was that only 20% use their own savings which is mostly made up of sales from previous season's production and other off farm activities such as retailing, gardening, local beer brewing, piece works, wages and charcoal burning,. While 15.83 percent indicated that they got their credits from farmers' organisations, and 61.8 percent do not have any source of credit. Table 5 gives distribution of households and farm characteristics of the sampled smallholder households:

4.6 STUDY MODELS

Two functional forms, the translog and the Cobb-Douglas were used in this study. The translog function was specified as:

$$\beta_o + \beta_1 lnl_i + \beta_2 lnla_i + \beta_3 lnf_i + \beta_4 lns_i + \beta_{12} lnl_i lnla_i + \beta_{13} lnl_i lnFi + \beta_{14} lnl_i lnSi +$$
$$\beta_{23} lnLailnFi + \beta_{24} lnLailnSi + \beta_{34} lnFilnSi + \beta_{11} 1/2 lnl_i{}^2 + \beta_{22} 1/2 lnLai^2 + \beta_{33} 1/2 lnFi^2 +$$
$$\beta_{44} 1/2 lnSi^2 + v_i - \mu_i$$

<div align="right">4.1</div>

was estimated where parameters $\beta_0, \beta_1, \ldots, \beta_{44}$ are vectors of unknown parameters to be estimated, and . $lny_i, lnl_i, lnla_i, lnf_i$ and lns_i are the natural logs of maize output, land, labour, fertiliser and seed, respectively. Vectors v_i and μ_i are as described in the preceding chapter. This functional form was estimated first to see whether it satisfied the structural properties of a production function knowing that it is a more flexible form. Owing to the presence of cross terms in the translog may not be directly interpreted as partial elasticities unless all coefficients of the cross terms are statistically equal to zero. Hence, the partial elasticity with respect to each input is calculated as:

$$\frac{\partial lnE(y_i)}{\partial lnx_{ji}} = \left\{ \beta_j + \beta_{jk} lnx_{ji} + \sum_{k \neq j} \beta_{jj} lnx_{ki} \right\} - c_i \left\{ \frac{\partial \mu_i}{\partial x_{ji}} \right\} \qquad 4.2$$

Where,

$$c_i = 1 - 1/\sigma \left\{ \frac{\emptyset(\mu_i/\sigma - \sigma)}{\Phi(\mu_i/\sigma - \sigma)} - \frac{\emptyset(\mu_i/\sigma)}{\Phi(\mu_i/\sigma)} \right\} \qquad 4.3$$

The elasticities which are analytically derived using equation (4.2) are now interpretable. Moreover, the CD stochastic frontier production function was specified as:

$$lny_i = \beta_o + \beta_1 lnl_i + \beta_2 lnla_i + \beta_3 lnf_i + \beta_4 lns_i + v_i - \mu_i \qquad 4.4$$

Where $lny_i, lnl_i, lnla_i, f_i$ and lns_i, are the natural logarithms of maize output (Y_i) land (L_i), labour (La_i), fertiliser (F_i) and seed (S_i), respectively, while $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, v_i$ and u_i are vectors of unknown parameters to be estimated.

Additionally, a logit model was used to regress efficiency scores on farmers' efficiency scores. Identifying and analysing the determinants of efficiency/inefficiency is very essential since it forms the basis for informing agricultural policy on possibilities of improving smallholder productivity. The social-economic characteristics which were included and were therefore regressed against efficiency scores are age, sex, education level, years in farming, land ownership, household size access to credit and access to extension services. These were combined in the following logit model given that efficiency scores are bounded between 0 and 1 (Gujarati, 2003):

$$LnLo_i\sqrt{W_i} =$$

$$\alpha_1\sqrt{W_i} + \alpha_2\sqrt{W_i}Age + \alpha_3\sqrt{W_i}sex + \alpha_4 edu + \alpha_5\sqrt{W_i}occupation + \alpha_6\sqrt{W_i}land\ ownership +$$
$$\alpha_7\sqrt{W_i}household\ size + \alpha_8\sqrt{W_i}years\ in\ farming + \alpha_9\sqrt{W_i}access\ to\ extension +$$
$$\alpha_{10}\sqrt{W_i}access\ to\ credit\ services + \mu\sqrt{W_i}$$

$$4.5$$

Where;

$LnLo_i = Ln\left(\frac{Eff_i}{1-Eff_i}\right)$ is the natural logarithm of the *odds ratio* such that a unit change in weighted determinant of a household head (or respondent) will result in a α_i change in the weighted log of the odds. Eff_i is the individual farmer's technical and allocative efficiency.

Additionally, taking the antilogarithm of the estimated logit model expressed as equation 4.5, the weighted odds ratio is obtained. If we further divide the logit with the associated

weight $\sqrt{W_i}$ we get the unweighted logit, and the antilog of the unweighted logit is the odds ratio. $\alpha_1, \alpha_2, \ldots, \alpha_{10}$ are unknown parameters to be estimated, $\mu \sim N\left[0, \left(\frac{1}{N_i, Eff_i(1-Eff_i)}\right)\right]$, and $\sqrt{W_i}$ is the weight meant to correct for heteroskedasticity in the error term such that $\mu \sim N(0,1)$. That, is the error term has a constant variance.

The rate of change of efficiency is given by;

$$\frac{dEff_i}{dDet_i} = \alpha_i * Eff_i(1 - Eff_i)$$ 4.6

Eff_i is as defined above while Det_i are the determinants of farm level efficiency such as age, sex, occupation, years in farming, etcetera, and α_i is as defined above. All, except the *AGE, OCCUPATION* and *YEARS* in farming variables, are dummy variables. *SEX* was defined as 1 for the female respondent and 0-otherwise. *EDU* was categorised in to three, namely 'no education', 'primary education' and 'post primary education'.

For each of these categories 1 was entered for and 0 for otherwise. LAND ownership was also categorised into 0-5ha and 6-20ha, 1 was entered for an affirmative response to each category and 0- otherwise. On access to extension services dummy, 1 implied *yes* and 0-*otherwise*. Finally, the access to credit services dummy was split in to three: 'No credit source' and Credit from farmers organisations.

CHAPTER 5

RESULTS AND DISCUSSION

5.1   INTRODUCTION

In this chapter, the objective was to summarise and present results from the study by objective. In section 5.2 the translog and Cobb-Douglas stochastic frontier production functions are estimated using production data of smallholder maize producers of Chongwe District. In section 5.3 smallholder maize producers' technical efficiency is derived. This together with input prices and using the self dual characteristics of the Cobb-Douglas, a cost function is derived, which forms the basis for estimating allocative and economic efficiency. In section 5.4, efficiency scores are regressed against the socio-economic characteristics such as age, sex, education level, years in farming, access to credit services, membership to cooperative, and so on, to determine how these factors affect farmer efficiencies. The section ends with a summary in section 5.5.

5.2   ESTIMATION OF THE TRANSLOG AND COBB-DOUGLAS PRODUCTION FRONTIERS

Under this objective, the main purpose was to estimate stochastic frontier production functions for smallholder maize producers using the translog and Cobb-Douglas production functions. The OLS and ML estimates from the translog frontier function are shown in Table 6. From production economics theory, for a production function to make sense it must satisfy all the structural properties. That is, this production function should be non- decreasing in inputs, non-increasing in outputs, linearly homogenous and concave in all inputs if and only if all inputs coefficients are greater than or equal to zero and the sum of all input coefficients is equal to one (Coelli *et al*, 2005:12). In fact, it is expected that there exist a positive relationship between maize output (y_i) and all the inputs land (l_i),

Table 6 OLS and ML estimates of the translog SFPF

Variable	Mean	Parameter	OLS estimates (standard error)	ML estimates (standard error)
Intercept		$\beta0$	-59.50 (306537.01)	-59.1238*** (0.9603)
Land		$\beta1$	-37.875*** (168059.02)	-37.1556*** (0.8339)
Labour		$\beta2$	-0.77571 (1.6195)	-0.81244 (0.7204)
Fertiliser		$\beta3$	19.75 (88248.61)	19.7224*** (0.6673)
Seed		$\beta4$	7.75*** (32389.20)	7.6795*** (0.9165)
		$\beta12$	-9.9688 (43885.40)	-9.6826*** (0.5944)
		$\beta13$	0.09069 (0.1614)	-0.04083 (0.1225)
		$\beta14$	0.07699 (0.3261)	-0.08151 (0.2555)
		$\beta23$	10.375 (46690.)	9.8601*** (0.8366)
		$\beta24$	-0.1567 (0.4402)	-0.1218 (0.2896)
		$\beta34$	6.6718 (29458.11)	6.7778*** (0.2843)
		$\beta11$	0.05859 (1402.30)	-0.2763 (0.4460)
		$\beta22$	0.03699 (0.2607)	0.08894 (0.1736)
		$\beta33$	0.07132 (0.5155)	0.1749 (0.3769)
		$\beta44$	-6.78 (29458.11)	-6.5355*** (0.4265)
Sigma-squared		$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.1018	0.0998*** (0.01812)
Gamma		$\gamma = \sigma_u^2 / \sigma^2$		0.99999987*** (0.0001908)
LLF			-25.18	40.72

***statistically significant at 1%, **statistically significant at 5% and *statistically significant at 10%

~ 66 ~

labour (la_i), fertiliser (f_i) and seed (s_i), which simply means that all coefficients should be positive.

However, the coefficients of the translog stochastic frontier do not have a straight forward interpretation as the output elasticities with respect to each of the inputs are functions of the first and second order coefficients (Alvarez & Gonzalez (1999:8), Nchale (2007:20), Onumah & Acquah (2010:829) Wadud (2003:117) and Zhang & Xue (2005:25)). Only in situations where all coefficients in cross terms (and second order) are statistically equal to zero can the coefficients of the single terms be interpreted directly. Thus to determine whether the coefficients in the second order terms were equal to zero, they were tested under the null hypothesis $H_o: \beta_{jk} = 0$ and the alternative hypothesis $H_A: \beta_{jk} \neq 0$ represents the cross terms $\beta_{13}, \beta_{14}, \beta_{23}, \beta_{24}, \beta_{34}, \beta_{11}, \beta_{22}, \beta_{33}, \text{and } \beta_{44}$. The decision rule was to reject the null hypothesis if the absolute value of the t-statistic was greater than the $t_{critical}$ at one, five or ten percent confidence limit. As can be seen from Table 6. Some of the coefficients of the cross terms are significant while others are not, implying that the coefficient are not directly interpretable. Therefore, partial elasticities of output with respect to inputs are estimated because they permit the evaluation of the effect of changes in the amount of an input on the output. Hence, the parameter estimates are discussed in terms of output elasticities evaluated at the mean values with respect to the various inputs. Table 7 shows elasticities with respect to each input evaluated at the mean output.

As can be seen from Table 7 all elasticities are positive. A positive relationship between maize output and inputs is expected as per structural properties of a production function. The positive elasticities shown in Table 7 confirm this positive relationship between maize output and the inputs. Thus, the elasticity of 0.4918 for land implies that, other inputs held constant, a 1 percent increase in land under cultivation will result in 0.4918% increase in output. For labour: a one percent increase in labour utilisation will result in 0.9986 percent increase in maize output, all things held constant, while that for fertilizer means that a 1 percent increase in inorganic fertilizer use will result in 0.72 percent increase in maize output, other inputs held constant. Finally, the elasticity of 0.8234 for seed implies that for a 1 percent increase in seed planted output will increase by 0.8234 percent, other inputs

held constant. The estimated variance parameter $\gamma = 0.99999987$ implies that almost 99 percent of the variation in output is explained by the inefficiency effects of inputs use. In other words technical inefficiency effects are significant in stochastic frontier production function. The log likelihood function of 40.72 is significant indicating that the model was correctly specified.

Table 7: Elasticities for land, labour, fertiliser and seed evaluated at mean output

Input	Elasticity
Land	0.4918
labour	0.9986
Fertiliser	0.7200
Seed	0.8234
Return to scale	**3.04**

Source: Author's own construct

Obviously, the results show that all the inputs have the greatest effects on maize output, which shows the importance of these inputs in as far as augmenting households' maize output is concerned.

On the other hand, the OLS and ML parameter estimates of the Cobb-Douglas production frontier are shown in Table 8. From production economics theory, for a production function to make sense it must satisfy all the structural properties. That is, this production function should be non- decreasing in inputs, non-increasing in outputs, linearly homogenous and concave in all inputs if and only if all inputs coefficients are greater than or equal to zero and the sum of all input coefficients is equal to one (Coelli *et al*, 2005:12). Thus, it is expected that there exist a positive relationship between maize output (y_i) and all the inputs land (l_i), labour (la_i), fertiliser (f_i) and seed (s_i), which simply means that all coefficients should be positive.

All the coefficients were tested under the null hypothesis: $H_0: \beta_0 = 0$ while the alternative hypothesis was $H_A: \beta_0 \neq 0$. The decision rule was to reject the null hypothesis if the

absolute value of the *t*-statistic was greater than the $t_{critical}$ at one, five or ten percent confidence limit. Since all *t*-statistics for the coefficients were greater than the $t_{critical}$ at 1 percent, the null hypothesis was rejected. Therefore, as can be seen from Table 8, all the coefficients (parameter estimates) are positive as expected and that they are all statistically significant which simply means that they have a positive contribution towards output. Additionally, the sum of input coefficients is 1.1 meaning that the farmers' production technology exhibits increasing returns.

Table 8 OLS and ML estimates of the Cobb-Douglas SFPF

Variable	Mean	Parameter	OLS estimates (standard error)	ML estimates (standard error)
Intercept		β_0	4.1733***	4.8113***
			(0.3302)	(0.3736)
Land	1.15	β_1	0.2259***	0.2187***
			(0.07660)	(0.0776)
Labour	131.77	β_2	0.1414***	0.1190***
			(0.04833)	(0.0443)
Fertiliser	390.00	β_3	0.2831****	0.1933***
			(0.06733)	(0.07412)
Seed	20.42	β_4	0.4614***	0.5491***
			0.1016	(0.1032)
Sigma-squared		$\sigma^2 = \sigma_u^2 + \sigma_v^2,$	0.05782	0.1270***
				(0.02471)
Gamma		$\gamma = \dfrac{\sigma_u^z}{\sigma^2}$		0.8856***
				(0.06457)
LLF			3.2988	7.5198

***statistically significant at 1%, **statistically significant at 5% and *statistically significant at 10%. Figures in parenthesis are standard errors.

Additionally, since all the coefficients are in natural logarithm form, they can also be interpreted as the partial elasticity of each input. For instance, the ML estimate of 0.2187 for land implies that other inputs held constant, a 1 percent increase in area cultivated for maize will increase maize output by 0.2187 percent, while that of 0.1190 for labour means that for a 1 percent increase in labour use maize output will increase by 0.1190 percent. Similarly, other inputs held constant, a 1 percent increase in fertiliser and seed use will

result in 0.1933 percent and 0.5491 percent increase in maize output, respectively. Moreover, the estimated variance parameter $\gamma = 0.8856$ implies that almost 89 percent of the variation in output is explained by the inefficiency effects of inputs use. In other words technical inefficiency effects are significant in stochastic frontier production function. The log likelihood function of 7.5198[6] is significant indicating that the model was correctly specified.

Notice that the coefficient for seed is largest indicating the importance of using certified seeding the production by the smallholder farmers. In Zambia smallholder maize producers have in the past used recycled seed which is partly the reason why yields have been poor. Hence using certified seed in this case proves that it augments output even more.

However, comparing the elasticities computed for the two functional forms, the translog shows labour to have the largest elasticity contrary to the CD functional form where seed had the biggest elasticity. [7]This is contrary to the reality as the opportunity cost of unskilled labour among smallholder farmers is low which makes it the most abundant resource. Land, Fertiliser and hybrid seed inputs are vital in maize production among this group of farmers and can be quite limiting. Fertiliser is the scarcest of the four inputs as it is quite expensive and almost unaffordable to the majority of the smallholder farmers. Seed, though expensive, has an alternative as households can easily use recycled seed and be able to grow and produce a crop (of course the price for using recycled maize seed is low yields). Labour is the most abundant resource among most households and since it has a low opportunity cost it is considered as the most abundant of the four inputs. As for land, if one has to grow and produce a crop they should obviously have access to it. Thus, it is

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[6] This test statistic was tested under the null hypothesis, $H_0: \beta_0 = model\ not\ correctly\ specified$ while the alternative hypothesis was $H_A: \beta_0 = model\ correctly\ specified$. The decision rule was to reject H_0 if LLF>$X^2_{1dof} = 5.412$ —this was the mixed chi-square distribution at 1 degree of freedom.

[7]Nchare (200), Onumah (2010) and Wadud (2003) also interpreted elasticities in terms of scarcity/ abundance of the inputs.

considered as the major input and an important asset among smallholder farmers as lack of it not only means no crop production but also food insecurity.

5.3 MEASURING TE, AE AND EE FROM THE CD SFPF, AND TE FROM THE TRANSLOG STOCHASTIC FRONTIER PRODUCTION FUNCTION

5.3.1 Estimating technical, allocative and economic efficiency from the CD SFPF

The technical, allocative and economic efficiency scores estimated using the CD stochastic production function are presented in Table 9. TE ranges from 40.6 percent to 96.53 percent with a mean of 78.20 percent. The presence of technical inefficiency indicates the likelihood of raising output without increasing input use in the production process.

Table 9: Frequency distribution of efficiency estimates from the SFPF model

Efficiency level	TE		AE		EE	
	Number	Percent	Number	Percent	Number	Percent
<40	0	0	9	7.5	53	44.17
41-50	4	3.33	24	20	21	17.5
51-60	8	6.67	23	19.17	20	16.67
61-70	16	13.33	23	19.17	17	14.17
71-80	26	21.67	22	18.33	7	5.83
81-90	50	41.67	18	15	2	1.67
91-100	16	13.33	1	0.83	0	0
Total	120	100	120	100	120	100
Mean	78.20		60.08		46.58	
Minimum	40.6		33.57		30.00	
Maximum	96.53		89.62		79.26	
Standard deviation	0.125409		0.157589		0.136149	

Source: Author's own construct

This means that if the households were to operate on the frontier they would have to reduce their technical inefficiency by 21.8 percent. Similarly, if the most technically inefficient household were to operate on the frontier they would reduce their technical inefficiency by 59.4 percent. These results also means that if the average farmer in the sample was to achieve the technical efficiency level of his or her most efficient counterpart

in the sample, he or she would realize 19 percent more productivity[8]. Moreover, the results also show that technical efficiency in smallholder maize producers can be increased by up to 19 percent on average, under the current production technology. In simple terms, this result entails that using the present production technology and if key factors that currently constrain overall efficiency are adequately addressed, smallholder productivity could increase by almost one fifth. The ultimate effect of increased smallholder households' returns would be poverty reduction. This increase in efficiency and therefore productivity among smallholder maize farmers may result in significant rise in output which directly translates into a one fifth increase in returns.

By using the estimated parameters from the Cobb-Douglas SFPF, input ratios and the observed output levels, parameters of the corresponding dual cost function were derived. This formed the basis on which AE and EE were calculated. Hence, the dual cost frontier derived is:

$$ln\,c_i = -1.95 + 0.2025\,ln\,w_l + 0.1102\,ln\,w_{la} + 0.179\,ln\,w_f + 0.508\,ln\,w_s + 0.8994$$

$$42\,lny_i^* \qquad\qquad 5.1$$

Where C in this case represents the cost of production for the ith farmer, w_l is the rental price for land per hectare which was estimated at ZMK251111.56, w_{la} is the cost of labour per man-day also estimated at ZMK5659.236, w_f is the cost of fertiliser estimated at ZMK4000.41 per kilogram, and w_s is the seed cost also estimated at ZMK36000.00 per kilogram

The average allocative efficiency for the sampled households was 61.81 percent with a minimum and maximum of 33.57 percent and 92.14 percent, respectively. This result

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[8] This percent increase in efficiency is obtained for technical efficiency by using the expression 1 – (78.20/96.53)*100, where the figures are the mean and maximum levels of technical efficiency shown in Table 9

shows that smallholder farmers have room to improve their allocative efficiency by 38.19 percent if they are to operate on the frontier. Moreover, if the average farmers had to achieve allocative efficiency of the most efficient household they have to reduce their cost by 32.9 percent. The least allocative efficient household will on the other hand have to reduce costs by 63.56 percent.

The minimum economic efficiency for the sampled households was 30 percent while the maximum was 79.26, with a mean of 47.88 percent. Given the mean economic efficiency of 47.88 percent, it means that households will have to improve their cost efficiency by 52.12 percent if they are to operate on the frontier. Additionally, if the average household were to achieve cost efficiency for the most efficient household in the sample they have to improve their cost efficiency by 39.59 percent. Least efficient household will in this case have to improve his/her cost efficiency by 62.15 percent.

By looking at the average figures for TE, AE and EE it is clear that the smallholder farmers are technically efficient but are not allocative and economically efficient. This means that solving allocation problems for this group of farmers is much more critical for improving overall efficiency than solving technical problems. There are environmental, economic and institutional factors which affect allocative and economic efficiency. In fact these factors affect each household so uniquely that their AE and EE are different. Environmental factors may include poor rainfall patterns, drought/floods, declining soil fertility as a result of nutrient mining and poor farming practice which results into land exhaustion. Poor rainfall patterns, drought and floods lower the crop yields which results in reduced output and reduced earnings. This is what effects the farmer's AE and EE. Declining soil fertility as well as poor farming practices affect the soil nutrients which entails over application of fertiliser per unit area which increases allocative costs, resulting in variable AE and EE among farm households. Institutional factors include information asymmetry, incomplete contracts, lack of access to extension services, poor road infrastructures, land ownership/ rights, etcetera. All these and other factors affect the smallholder households' AE and EE differently. Finally, economic factors which equally affects smallholder farmers' AE and EE include high transaction costs, distance to the market for the produce, the price per kilogram of maize, etcetera. Thus, there is need to critically consider and analyse

environmental, economic and institutional issues that affect smallholder producers' allocative and economic efficiency (Bravo-Ureta (1997), Debela, *at al*. (n.d) & Tchale 2009). Figure 4 shows the graphical presentation of efficiency scores.

Figure 4: Graphical presentation of households, TE AE and EE scores
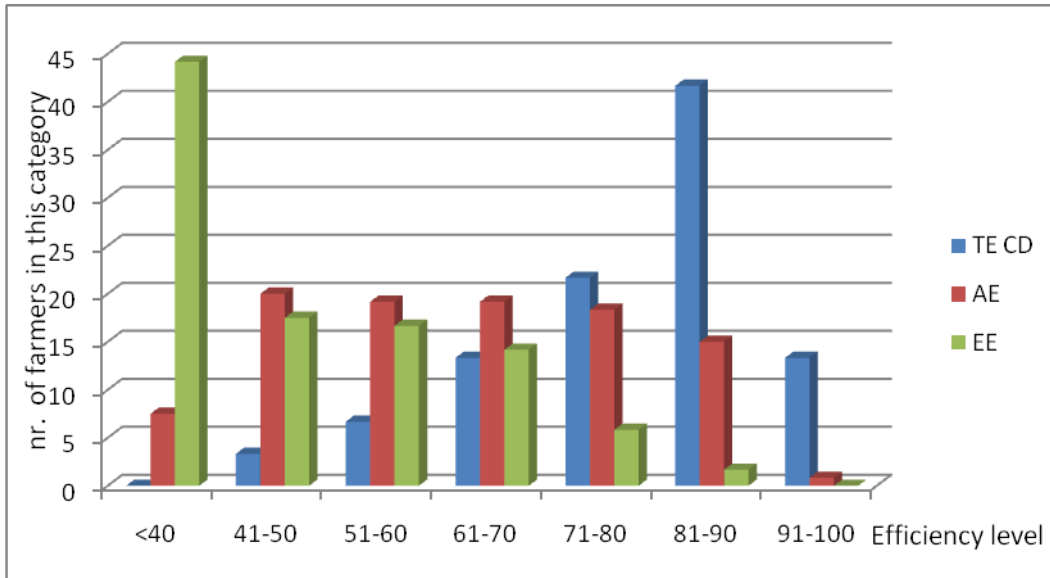
Source: Author's own construct

5.3.2   <u>Estimating TE from the translog stochastic frontier production function</u>

Technical efficiency estimates from the translog frontier production function are shown in Table 10. As can be seen, TE ranges from 40.44 percent to 99.94 percent with a mean of 76.70 percent. The presence of technical inefficiency indicates the likelihood of raising output without increasing input use in the production process. The average technical efficiency of 76.70 percent also implies that households will have to reduce their technical inefficiency by 23.3% in order to operate on the frontier. Moreover, if the average efficient smallholder household in the sample was to achieve the technical efficiency level of his or her most efficient counterpart, he or she would realize 23.25 percent more productivity[9].

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[9] This percent increase in efficiency is obtained for technical efficiency by using the expression 1 – (76.7/96.94)*100, where the figures are the mean and maximum levels of technical efficiency shown in Table 9

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Similarly, if the most inefficient household has to achieve efficiency of the least inefficient household in the sample they will have to achieve 59.54 percent more productivity.

Table 10: TE scores from the translog frontier PF

TE	Households	Percent
<40	1	0.83
41-50	4	3.33
51-60	9	7.50
61-70	25	20.83
71-80	27	22.5
81-90	34	28.33
91-100	20	16.67
Total	**120**	**100.00**
Mean	**76.70%**	
Minimum	**40.44%**	
Maximum	**99.94%**	
Standard deviation	**0.137664**	

Source: Author's own construct

Figure 5 shows the scatter graph of technical efficiency for the smallholder maize producers measured using the Cobb-Douglas and the translog frontier production functions. The figure shows clearly that the two graphs are positively correlated. This is

Figure 5: Scatter graph of TE under the CD and the translog
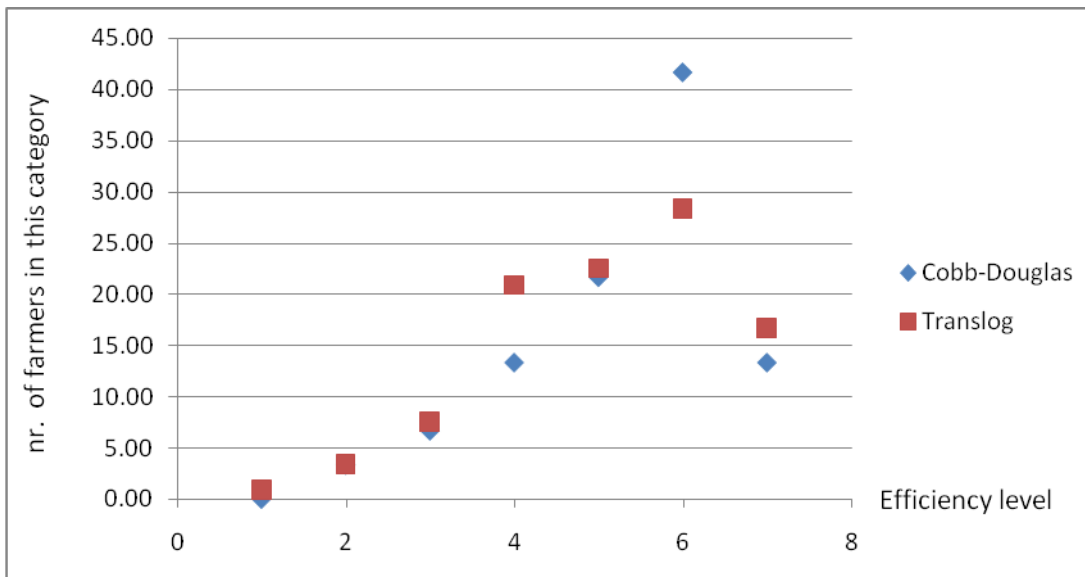
Source: Author's own construct

supported by carrying out an *F*-test to see whether there is significant difference between the means of the two data sets. Using the null hypothesis, $H_o: \bar{x}_1 = g\,\bar{x}_2 = 0$ and the alternative hypothesis, $H_A: \overline{x}_1 \neq \bar{x}_2 \neq 0$. Using $\alpha = 0.05$, reject H_o if $F_{calculated}$ is greater than $F_{critical}$ = 1.38 at degrees of freedom. Since both F statistics calculated are less than the $F_{critical}$ = 1.38, we do not reject H_o. Therefore, the conclusion is that there is no significant difference between the two mean efficiencies from the CD and the translog.

5.4 EFFICIENCY DETERMINANTS AMONG SMALLHODER MAIZE PRODUCERS

Results of the logit model showing determinants of farm-level efficiency are shown in Table 11. The table also includes estimated coefficients and the *p*-values together with the significance levels. Only land ownership, household size, years in farming and access to credit services were significant in explaining farm-level efficiency. The coefficients of land ownership were positive and significant at 1 percent meaning that households who own land are more efficient than those who do not but rather rent land for maize production. In other words the marginal effect of 0.636581 for land up to five hectares imply that for 1 unit increase in land owned by smallholder producer the weighted log of odds increases by 0.6365841. Taking the antilogarithms, 1 unit change in land ownership by a household will increase the weighted odds ratio by 1.89 (antilog of 0.6365841). Therefore, a 1 unit increase in land owned by a household will improve their efficiency by 14.43 percent[10]. This finding is similar to most findings in literature which shows a positive relationship between land size and farm level efficiency and smallholder farmers (Bravo-Ureta & Pinheiro, 1997:61). By similar argument, the marginal effect of 0.0203171 for years in farming imply that a year increase in total number of years spent in farming the weighted log of odds will reduce by -0.0203171. At this marginal effect, the farmer's reduce by 0.5 percent (-0.0203171*0.494920899*0.5050791). For household size, a unit increase in household size increases the weighted odds ratio by 0.149214 and increases farm level efficiency by 3.3 percent.

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[10]This figure is obtained by calculating the rate of change of efficiency at the marginal effect of 0.6365841 for a household who own up to 5 ha of land $\frac{dEff_i}{dDet_i} = 0.6365841 * 0.654979238(1 - 0.654979238)$

Table 11: Logit model results of determinants of technical efficiency

Variable	CD Marginal effect (p-value)	Translog Marginal effect (p-value)
Age	. -.0000435	0.0037412
	(0.989)	(0.763)
Sex(1-female, 0-male)	. -.0464687	-0.2335499
	(0.481)	(0.315)
Education level		
No education(1-Yes, O-otherwise		-0.2643024
		(0.499)
Primary education (1-Yes, 0-otherwise)	-.0211551	-0.3411219
	(0.781)	(0.289)
Post primary (1-Yes, 0-otherwise)	.0330401	
	(0.768)	
Occupation	-.1501194	0.177205
	(0.562)	(0.842)
Land ownership		
Land 0-5ha (1-Yes, 0-otherwise)	.6365841***	0.6961146
	(0.002)	(0.417)
Land 6-20ha (1-Yes, 0-otherwise)	.7149901***	1.009053
	(0.001)	(0.264)
Household size	0.149214*	0.0387385
	(0.097)	(0.277)
Years in farming	-.0203171**	-0.0191777
	(0.026)	(0.159)
Access to extension services(1-Yes, 0-otherwise)	.0713109	0.627956**
	(0.340)	(0.026)
Access to credit services (1-Yes, 0-otherwise)	.0970417	0.125876
	(0.772)	(0.878)
No credit source	-1.255504***	.2387515
	(0.006)	(0.787)
Farmer's organisation	1.009757***	0.5238041
	(0.007)	(0.533)
Intercept	30.76179***	-0.1178514
	(0.000)	(0.938)

Note: *statistically significant at 10%, ** statistically significant at 5% and *** statistically significant at 1%

The results further show a negative relationship between farm TE and 'No credit source'. That is, farmers with no credit source had a reduced efficiency of 30.10 percent (*obtained by computing the rate of change of efficiency using equation 4.6 in chapter 4*) where as for the farmers who had access to credit services the model indicates that their efficiency had increased by approximately 19.76 percent. Thus, smallholder access to credit services improves their efficiency by 20 percent while lack of it reduces efficiency by 30 percent. Moreover, in this study age (*though not statistically significant at any confidence level*), had a negative effect on farm level efficiency. That is, the older a farmer got the less efficient in production that they become. This is consistent with literature reviewed which showed age as having mixed effects on efficiency. This could be attributed to the fact that older farmers may have more farming experience, stick to tradition farming and methods and are less likely to adopt new technologies. Younger farmers may on the other hand be more adaptive to changing technological innovation even if they have little experience.

The SEX dummy was also negative and statistically insignificant. Although this household characteristic may have some effect on the technical efficiency, in this particular study it was included as one of the determinants of farm level efficiency to show where female headed households were more efficient than their male counterparts. In other words, the inclusion of SEX dummy in the model was intended to determine whether being male or female has an effect on technical efficiency of smallholder farmers. The marginal effect of -.0464687 showed that a female headed household had reduced farm level efficiency by 0.88 percent. Education level was equally included so as to determine whether this factor has an effect on efficiency. Literature actually shows that farmers who are well educated tend to exhibit higher levels of efficiency compared to those with no education[11]. The main reason for this is that educated farmers are able to gather, understand and use information from research and extension more easily than illiterate farmers, and that educated farmers are very likely to be less risk-averse and therefore more willing to try out modern technologies. In this study education was categorised into 'no education', 'primary education' and 'post primary education'. The marginal effect for 'no education' was missing, while marginal effect for 'primary education' was -0.004085. This implied that

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[11] TChale (2009), Bravo-Ureta and Pinheiro (1997) are among the authors who have demonstrated a positive relationship between the farmer's education level and efficiency.

Table 12: Determinants of AE and EE

Variable	AE Marginal effect (p-value)	EE Marginal Effect (P-value)
Age	0003608	-0.0001
	(0.927)	(0.985)
Sex (1-female, 0-male)	.1084687	.1530892
	(0.150)	(0.145)
Education level		
No education(1-Yes, O-otherwise	-2.919356***	-1.496414
	(0.000)	(0.121)
Primary education (1-Yes, 0-otherwise)	-2.845875***	-1.408315
	(0.000)	(0.142)
Post primary (1-Yes, 0-otherwise)	-2.913381***	-1.280673
	(0.000)	(0.774)
Occupation	-.1406947	.249277
	90.597)	(0.517)
Land ownership		
Land 0-5ha (1-Yes, 0-otherwise)	.7344687***	.64015
	(0.029)	(0.108)
Land 6-20ha (1-Yes, 0-otherwise)	.5337601	.4958587
	(0.122)	(0.230)
Household size	.0019709	.021013
	(0.864)	(0.190)
Years in farming	.0038749	-.0040271
	(0.360)	(0.504)
Access to extension services(1-Yes, 0-otherwise)	.0288828	.1298966
	(0.742)	(0.292)
Access to credit services (1-Yes, 0-otherwise)	-.1084082	-.1821071
	(0.208)	(0.140)
Disaster experience (1-yes, 0-otherwise)	.0219842	-.0660074
	(0.794)	(0.571)
Intercept	65.98672***	6.039213
	(0.000)	(0.184)

Source: Author's own construct

smallholder farmers who have gone up to primary education had reduced efficiency by 0.41 percent. On the other hand, study showed that there is a positive relationship

between efficiency and 'post primary education' level. In other words, farmers who have gone up to 'post primary education' were more efficient (the more years a farmer spends in school the more efficient they are expected to be) this is evident from the marginal effect of .0330401 which is interpreted as: a year increase in the number of years spent in education increases the weighted odds ratio by 0.0330401 and consequently raises the farmers efficiency by 0.66 percent. Results of the second stage regression between TE obtained using the translog and household characteristics are also shown in Table 11. Some important observations are made in the second stage regression. The most significant one are the positive relationship between access to credit and TE, and the negative relationship between TE and no access to credit. Obviously this has a huge policy implication for the policy makers in the agriculture sector. Thus, from the policy point of view access to affordable credit services will improve smallholder efficiency than lack of it. This simply means that there is need to improve the credit facilities for smallholder farmers if their production efficiency has to improve from the current state.

Both EE and AE were also regressed against Age, sex, education level, years in farming, occupation, access to extension, access to credit services and disasters experiences to see the effect of these factors on the efficiencies. Results obtained are shown in Table 12. Household characteristics which affect their AE and EE can be categorised into economic, environmental, technological and institutional factors. The most prominent ones found in literature are access to credit, access to extension, access to market, infrastructures (good or poor), farming practices, soil fertility, age, gender, education level, occupation and years in farming.

In this study only education level and land ownership were statistically significant in explaining allocative efficiency while none was significant in explaining economic efficiency of the sampled households. Although not statistically significant age, sex, land ownership, access to extension and years in farming had a positive effect on AE while education level, main occupation and access to credit services are negatively related to allocative efficiency. Age education level, years in farming, access to credit services and disasters experienced have a negative effect on economic efficiency of the sampled households

while sex, land ownership, household size and access to extension are positively related to economic efficiency.

Therefore, based on the results obtained as well as observations from the literature reviewed, it is important to find ways of addressing allocative and economic efficiency knowing that the factors which affect it are social, economic, environmental and institutional factors. In the socio-economic factors there is need to address issues of education so that majority of the farmers become literate, while to address environmental issues (e.g. poor land practices which lead to nutrient depletion from the soils), there is need to strengthen extension systems so as to teach the farmers better farming practices. To address economic issues (for example. high transport cost due to poor roads infrastructure) and institutional issues (access to credit) there is need for government to invest highly in infrastructure development as this will not only lead to reduction in transport costs but will also reduce transaction costs and information asymmetry. In other words, Government should help create credit facilities to provide affordable loans to this group of farmers. Additionally, there is need to improve extension systems to help educate farmers about better farming practices and other innovative technologies to further improve their efficiency in production. Issues of land ownership among this group of farmers needs to be addressed as this will not only raise confidence but will also ensure that their cost of production is reduced since there will be no need for payment of rental charges, and that farmers will adhere to good farming practices knowing they own title to land.

CHAPTER 6

CONCLUSIONS AND POLICY IMPLICATIONS

6.1 CONCLUSION

The main objective of the study was to assess technical, allocative and economic efficiency of smallholder maize producers in Chongwe district using the stochastic frontier approach. Two models were used to measure technical efficiency, the Cobb-Douglas and the translog production frontiers while allocative and economic efficiency were derived using the Cobb-Douglas production frontier. Using these models, results show that there is a significant level of inefficiency as illustrated by the following coefficients. Technical Efficiency (TE) estimates range from 40.6 percent to 96.53 percent with a mean efficiency of 78.19 percent, while Allocative Efficiency (AE) estimates range from 33.57 to 92.14 percent with a mean of 61.81 percent. The mean Economic Efficiency (EE) is 47.88 percent, with a minimum being 30 percent and a maximum of to 79.26 percent. The results therefore indicate that inefficiency in maize production in Chongwe District is dominated by economic and allocative inefficiency. Additionally, in the two-stage regression farm households characteristics: age; sex; education level; occupation; years in farming; land ownership; household size; access to extension and access to credit services; are regressed against technical efficiency scores using a logit function. Results obtained shows that land ownership, access to credit services, access to extension services and education level of up to post primary (secondary and tertiary) have a positive influence on the households' technical efficiency. On the other hand, age of the household head; female headed household and lack of education (though not statistically significant at any level confidence level) have a negative influence on this group of maize producers. Similar access to extension services, membership to producer organisation, access to credit and disaster experienced on the farm such as floods, drought and hail, are regressed against AE. The result shows that access to extension services, access to credit services, membership to cooperatives and natural calamities all affect AE.

Results therefore, show that there is a great deal of both allocative and economic inefficiency among smallholder maize farmers than there is technical inefficiency. To address these inefficiencies observed there is need to design policies that will ensure that environmental (e.g. poor land practices which lead to nutrient depletion from the soils), economic (e.g. high transport cost due to poor roads infrastructure) and institutional issues (access to credit) are addressed. In other words, Government should help create credit institutions to provide affordable loans to this group of farmers. Additionally, there is need to improve extension systems to help educate farmers about better farming practices and other innovative technologies to further improve their efficiency in production. Issues of land ownership among this group of farmers needs to be addressed as this will not only raise confidence but will also ensure that their cost of production is reduced since there will be no need for payment of rental charges, and that farmers will adhere to good farming practices knowing they own title to land.

6.2 POLICY IMPLICATIONS

Based on the results of the study which showed a great deal of allocative and economic inefficiencies among this group of farmers, it becomes important that issues that directly affect AE and EE are addressed. In general, the issues which affect this particular group of smallholder maize producers include environmental, technological, economic and institutional factors.

In this study, the environmental dummy (as indicated by the disaster experienced) show that presence of disaster reduces AE by almost 98 percent and EE is reduced by almost 94 percent. The environmental factors which affect farmers' allocative and economic efficiency include poor land practices, floods, drought and hail. Poor land practices such as conventional ways of farming disturbs the soil structure causing soil erosion and wearing of soil nutrients. When this is the case soil requires application of more fertiliser in order for the crop to growth. However, too much fertiliser application per unit area means high cost of production which leads to allocative inefficiency. Drought/floods and hail on the other hand results in stunted growth or even total crop failure which lowers returns. In addressing environmental factors, there is little that can be done as regards natural

calamities but as for the human factors such as poor farming practices there is need to strengthen extension systems so that farmers are taught better farming methods such as conservation farming. This will not only help in saving farmers' costs associated with purchasing fertiliser but it will also help conserve the soil and the environment. Technological factors include such issues as better farming methods like conservational farming as opposed to conventional farming. This farming practice though labour intensive during weeding offers a cheaper farming method as it requires relatively lower fertiliser application than what is required in the conventional farming. Thus, there is also an appeal to the government to create an extension system which will introduce such technologies as well as teach the farmers about other new ways of farming.

Economic factor as indicated by the 'access to credit facilities dummy' shows that lack of access to credit facilities by smallholder maize farmers reduces AE by almost 90 percent while EE reduces by 83 percent. Economic factors include high transport cost due to poor roads infrastructure, poor market for the crop, etcetera also affects the farmers' overhead costs which leads to allocative inefficiency. These factors can be addressed by designing and implementing policies which will ensure development of such infrastructures. The institutional and policy issues such as markets and other public provisions are just as important as technological factors in improving overall efficiency in the smallholder subsector. Issues such as access to credit facilities may reflect the declining value/cost ratios that are caused by input costs increasing faster than output prices. Issues of land ownership among this group of farmers needs to be addressed as this will not only raise confidence but will also ensure that their cost of production is reduced since there will be no need for payment of rental charges, and that farmers will adhere to good farming practices knowing they own title to land.

6.3   STUDY LIMITATIONS AND AREAS OF FUTURE RESEARCH

6.3.1   Study limitations

The following were the limitations of the study:

- The approach used in this study has potential endogeneity problems. Literature suggests that distance function approach do not suffer from endogeneity. It would therefore be interesting to analyse the robustness of these conclusions when TE, AE and EE for the sample is estimated.

- The study only employed the parametric approach which only told one side of the story. Therefore it would have been nice if the non-parametric approach was equally used in order to compare the results.

- Strictly speaking, results of this study are only applicable to the sample and any generalisation of the results may not be valid as the households in this sample may have their own unique characteristics which may differ from those of the other household in another area.

6.3.2 <u>Areas of future research</u>

In this study the parametric stochastic frontier approach was used. This approach involves imposing functional forms on the production functions and making assumptions about the error terms. By so doing makes the efficiency estimates suffer from simultaneity bias and other endogeneity problems. Therefore, this study could be conducted using other approaches such as the distance function and the non-parametric approaches. In addition, the study was done on a sample of maize farmers only. This can be extended to other crops such as tobacco, soybeans, millet, cassava, and etcetera.

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