TECHNICAL AND ALLOCATIVE EFFICIENCY OF SMALLHOLDER MAIZE FARMERS IN ZAMBIA

By

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I, Susan Chiona declare that this dissertation:

(a) Represents my own work;
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APPROVAL

This dissertation of Susan Chiona has been approved as partial fulfillment of the requirements for the award of the degree of Master of Science in Agricultural Economics by the University of Zambia.

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ABSTRACT

Maize is Zambia's staple food and is widely grown by smallholder farmers throughout the country. The productivity of this crop has been persistently low despite various private and public sector interventions. This paper determines the technical and allocative efficiency of smallholder maize farmers in Zambia. Most studies on efficiency in Zambia have used parametric methods to estimate efficiency. These methods ignore the importance of individual farms. This study appreciates individual farms and hence opts to use a non-parametric method of estimation, the Data Envelopment Analysis (DEA). It further links the observed efficiency or inefficiency to farmers' socio-economic characteristics through regression analysis.

The DEA results indicate very low levels of technical and allocative efficiency among smallholder maize farmers. Technical efficiency scores range from 0.071 through 1 while allocative efficiency ranges between .001 and 1. On average, farmers are 30 percent technically efficient and only 1.18 percent of the farmers are fully efficient. Allocatively farmers are 12 percent efficient with only 0.33 percent being efficient. This means that on average, the level of inputs (land, labour, seed and fertilizer) used by farmers can be reduced by 70 percent while costs can be reduced by 88percent without affecting the current level of output.

Regression results have shown that use of certified hybrid seed, livestock ownership, and education attainment of household head improves both technical and allocative efficiency. The same results further show that involvement in community agricultural activities, use of mechanized tillage methods and use of organic or chemical fertilizers improves technical efficiency among farmers. Farmers who used certified hybrid seed are likely to get higher yields while farmers belonging to agricultural association or are involved in community agricultural activities are expected to have better access to extension services than those who are not.

Based on these findings, policy makers in agriculture should focus on strategies to reduce input use while maintaining current production or increase output from the current level of inputs. Policy makers should therefore promote ownership of livestock which acts as a social buffer and allows farmers to access expensive but efficiency promoting technologies like fertilizer and certified seed while encouraging use of affordable mechanized tillage through draught power to reduce on the time and labour spend in maize production. Given that certified hybrid seed and fertilizer use improves efficiency and that farmers use improper application rates, policy makers should devise strategies on how best to provide extension services to farmers to help them appreciate both the use of and adherence to recommended application rates to improve productivity. Improved extension services will help improve the level of output from the current level of inputs. Farmers groups should be encouraged and strengthened to improve access to market information and other extension services as results have shown that farmers belonging to associations are more efficient.

This study is dedicated to my lovely husband, Eric, smart son, Mark and cutie daughter, Esther. You guys are the dream team.

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LIST OF ABREVIATIONS

AMIC	Agriculture Marketing Information Center
BCC	Banker, Charnes and Cooper
BLUE	Best Linear Unbiased Estimator
CCR	Charnes, Cooper and Rhodes
CFS	Crop Forecasting Survey
CSA	Census Supervisory Area
CSO	Central Statistical Office
DEA	Data Envelopment Analysis
DFA	Distribution-Free Approach
DMUs	Decision Making Units
FDH	Free Disposal Hull
FSRP	Food Security Research Project
GAMS	Generalized Algebraic Modeling System
GDP	Gross Domestic Product
GRZ	Government of the Republic of Zambia
MACO	Ministry of Agriculture and Cooperatives
OPVs	Open Pollinated Varieties
PHS	Post Harvest Survey
PPS	Probability Proportional to Size
PSUs	Primary Sampling Units
SEAs	Standard Enumeration Areas
SFA	Stochastic Frontier Approach
SSA	Sub-Saharan Africa
TFA	Thick Frontier Approach
VIF	Variance Inflation Factor

CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture is the engine of growth in most economies in Sub-Saharan Africa (SSA) contributing at least 70 percent of employment, 40 percent of export earnings, 30 percent of Gross Domestic Product (GDP) and up to 30 percent of foreign exchange earnings (IFAD, 2002). In Zambia, the sector contributes 18-20 percent to GDP and provides a livelihood to 50 percent of the population. It also absorbs about 67 percent of the labour force (GRZ 2004) and remains the main source of income and employment for rural women, who constitute 65 percent of the rural population (GRZ 2006). Therefore, increases in rural incomes are expected to result in overall poverty reduction and food security.

However, agricultural productivity in Africa has declined over the last two decades leading to progressive increase in food imports. The low productivity prohibits farmers from earning significant returns from their enterprises and hence reduces farm incomes (GRZ 2006). With 28 percent of the population in SSA suffering chronic food insecurity, the need for efficient resource utilization cannot be over emphasized. Efficient resource use remains a major challenge for policy and initiatives which are targeted at improving livelihoods in the region (Kuriuki et al 2008).

1.1.1 Food Production Trends in Africa

In the early1960s, Africa was a leading agricultural exporter whereas Asia was faced with serious food shortages. However, by the mid-1960s, Asia had launched the green revolution, which is now supplying 50 million metric tons of grain to the world food supply each year. Africa has taken up the position of Asia and is the one now bearing the impact of the world food problem (Byerlee, 1997).

The food balance sheet in Africa has shifted from positive to negative. For example, between 1970 and 1985, food production grew by 1.5 percent while the population growth was 3 percent. This has in effect led to a decline in per capita food consumption, making Sub-Saharan Africa the only region in the world where average calorific intake has declined over time. The problem of reduced per capita food consumption is evident from of the growing reliance on food imports, food aid and rising poverty. Human population in Africa is expected to double to 1.2 billion by 2020, which will further increase demand for food (Byerlee, 1997). This calls upon researchers and policy makers to unearth new ways of dealing with the threatening food shortage challenge. The adoption of new technologies designed to enhance farm output and income has received particular attention as a means of accelerating economic development. However, output growth is not only achieved through technological innovation but also through the efficiency in which such technologies are used. Given the resource constraints faced by many countries in Sub Saharan Africa, improving the productivity of food producers through efficient use of available technologies offers the most viable channel to deal with the problem of food shortages and low unpredictable international food prices.

1.1.2 Maize Production in Zambia

Maize (*Zea mays L.*) originated from Latin America and its cultivation is considered to have begun by 3000 BC. It was introduced to West and East Africa in the 16th century. In Zambia maize ended up replacing sorghum and millet as the staple food. By independence time in 1964 maize already accounted for over 60 percent of the planting area (JAICAF 2008). In the 1960s, production volumes were relatively low. In the 1970 production volumes and planting area both increased as the government introduced chemical fertilizer subsidies and raised the producer prices in the 1970's. However, production volumes dropped in the 1980's and has remained low even with the introduction of high yielding varieties and input subsidy programmes. In the 1960's Zambia produced 0.57 - 0.77 million metric tons on a planting area of 0.75- 0.87 million hectares translating into a unit yield of less than 1 metric ton per hectare as shown in figure 1. In the 1970's productivity improved, unit yields rose beyond two metric tons per hectare and even reached 2.5 metric tons per hectare in some years.

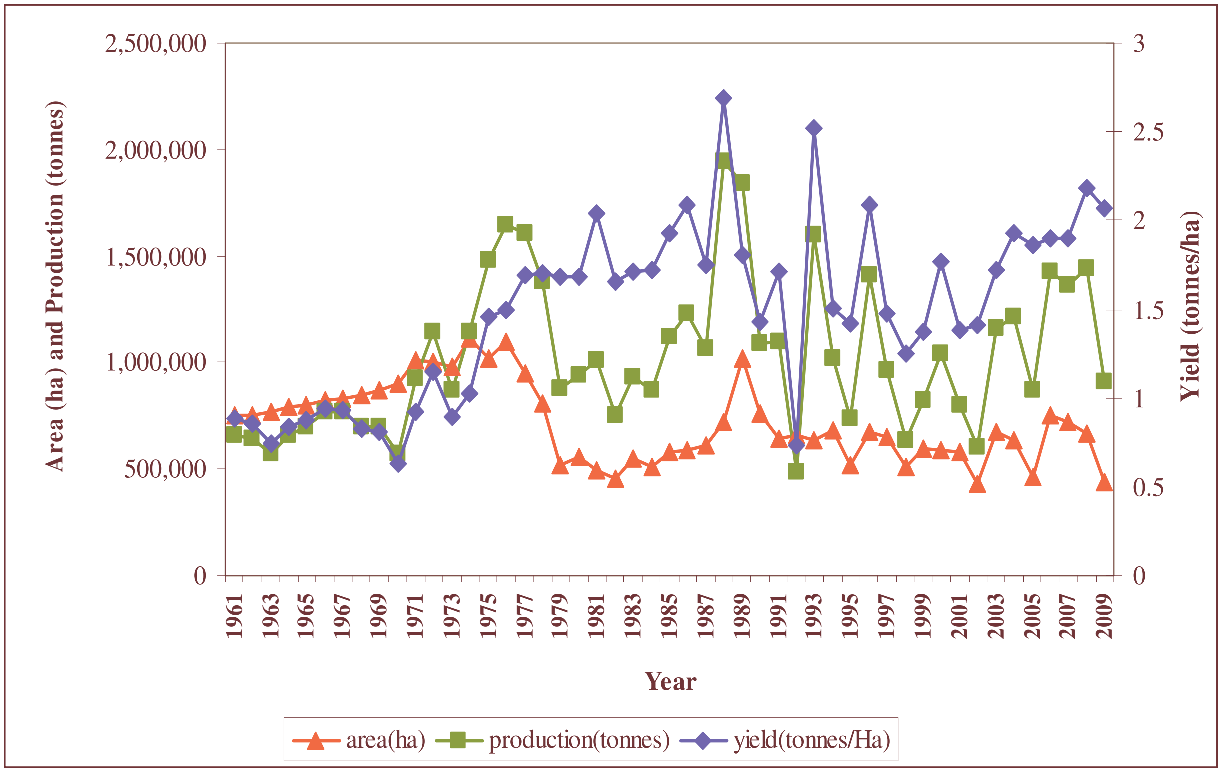

Figure 1: Annual Yield, Planting Area and Production Volumes
Adapted from FAOSTAT, 2011

However, Maize productivity stagnated between 1.3 and 1.8metric tons from 1997 to 2007 a level which is comparable to that of traditional varieties. A slight improvement was observed in the 2008 and 2009 farming season as productivity reached 2 metric tons per hectare.

Maize is Zambia's staple food and is grown widely throughout the country. It provides 60 percent of all calories consumed in Zambia. At the time of independence in 1964 and during the 1970s and 1980s, maize accounted for 60 percent of the crop growing area. However, this ratio has fallen below 30 percent since the 1990s. This is mainly because commercial farmers have shifted from maize to exportable crops with higher value addition such as cotton, soya beans and sunflower. Maize has also experienced substantial reductions in productivity, which is more acute among smallholder farmers who produce 79 percent of Zambia's 1.2 million metric ton annual food requirement (JAICAF, 2008). According the Post Harvest Survey-Supplemental Survey (PHS-SS) data 2004, there were an estimated 1,267,145 households in the 2003/04 marketing year. Roughly 78% to 80% of all these smallholder households plant maize. About 96% of the farms in these nationally representative surveys are in the small-scale (0.1 to 5.0 hectares) category, with the mean area per small-scale farm being 1.4 hectares. About 4% of the farms are in the "medium-scale" category (Zulu at el, 2008). The average, maize productivity among these smallholder farmers ranges between 1.2 and 1.6 metric tons per hectare against the potential of 5 and 10 metric tons for Open Pollinated Varieties (OPVs) and hybrid varieties, respectively (MACO/CSO/FSRP, 2008). This shows that smallholder farmers are technically inefficient since they are producing far below potential output given the existing technology.

1.2 Statement of the Problem

Efficient use of scarce resources in fostering agricultural production has long been recognized and has motivated considerable research into the extent and sources of efficiency differentials in smallholder farmers. Empirical evidence suggests that improving the productivity of smallholder farmers is important for economic development because small holder farmers provide a source of employment and a more equitable distribution of income (Bravo-Ureta and Evenson 1994). Accordingly, many researchers and policymakers have focused their attention on the impact that adoption of new technologies can have on increasing farm productivity and income (Hayami and Ruttan 1985; Kuznets 1966; Seligson 1982). However, during the last decade, major technological gains branching from the green revolution appear to have been largely worn out across the developing world. This suggests that consideration on productivity gains arising from a more efficient use of existing technology is necessary (Bravo-Ureta and Pinheiro 1997). The existence of shortfalls in efficiency means that output can be augmented without requiring further conventional inputs and without requiring new technology. If this is the case, then empirical measures of efficiency are necessary in order to determine the magnitude of the gains that could be obtained by improving performance in agricultural production with a given technology.

Agricultural efficiency studies have been carried out in many developing countries (Squires and Tabor, 1991; Rios and Shively, 2005; Shafiq and Rehman, 2000; Fletschner and Zepeda, 2002). However, few studies have looked at the efficiency of maize which is a staple food for many developing countries especially in Africa (Chirwa, 2007; Kibaara, 2005). Much of the existing literature on efficiency in maize has exclusively focused on technical efficiency. How farmers allocate their resources in response to price incentive is an important determinant of the profitability of the farming enterprise. Both technical and allocative efficiency are important in improving the productivity gains from existing technologies.

In Zambia, several studies have been carried out on productivity. For instance, Deininger *et al*. (1999) studied the relationship between macroeconomic policy and productivity. Kimhi (2003) looked at the relationship between plot size and maize productivity. Other studies have looked at the role of an efficient maize market policy in improving productivity (Abbink *et al.*, 2007; Zulu *et al.*, 2007). Even though the subject of technical and allocative efficiency is important, no studies have focused on these areas.

1.3 Objectives

The overall objective of this study was to determine the Technical and Allocative efficiency of smallholder maize farmers in Zambia.

The specific objectives were to:

i) Determine technical efficiency levels among Zambian smallholder maize farmers

ii) Determine allocative efficiency levels among Zambian smallholder maize farmers

iii) Identify farm and farmer characteristics affecting smallholder technical and allocative efficiency in maize production.

1.4 Significance of the study

This will be the first study looking at technical and allocative efficiency in maize production. It will therefore add to existing literature on technical and allocative efficiency as they relate to Zambia

The efficiency indices computed will reveal the extent of technical and allocative inefficiency among smallholder farmers. This reflects the existing potential for farmers to improve output without changing the level of inputs or produce the same output with far less inputs than they are currently using. Farm and farmer characteristics observed among efficient farmers will be used to formulate policy recommendations that will help policy makers to develop strategies that will help inefficient farmers. This will also be important in extension work as it will highlight farm and farmer characteristic more likely to enhance productivity among the farmers. NGO, private and public agencies will be able to focus their investments towards the promotion of those farm and farmer characteristics positively influencing productivity.

Considering that about 80% (PHS-SS 2004) of all farming household grow maize, increased productivity from efficient use of available technologies is expected to contribute towards poverty alleviation in the rural areas. Farming household will have better access to food through increased production and incomes.

1.5 Organization of the study

Chapter 1 highlighted the importance of the agriculture sector to the Zambia and Africa as a continent and the challenges of food shortages. It further discussed the importance of maize as a staple food for Zambia and the trends in production since independence. The remainder of the thesis is organized as follows: Chapter 2 contains a review of literature and includes a detailed discussion of maize in Zambia. It defines efficiency and examines the advantages and disadvantages of different approaches available for the estimation of a production frontier and the computation of relative technical efficiency scores. In addition, related studies and empirical studies are reviewed. Other approaches to the technical efficiency are briefly discussed. Chapter 3 presents the model specification and detailed discussion of the variables and data set utilized in the study. Chapter 4 discusses the results of the analysis while conclusions of the major findings and recommendations, and suggestions for further research are discussed in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature on agricultural efficiency and highlights the importance of agricultural efficiency in dealing with the problem of food shortages in Africa. It defines the various types of efficiency and examines the advantages and disadvantages of different approaches available for the estimation of a production frontier and the computation of relative efficiency scores. Finally, it looks at related past studies on efficiency using both parametric and non parametric methods.

2.2 Productivity and Efficiency

Productivity and efficiency are two different concepts except under the assumption of constant returns to scale. According to Fried *et al.* (2008), productivity of a producer is the ratio of its output to its inputs. This measure is easy to calculate if a producer uses a single input to produce a single output. But when multiple inputs are used to produce several outputs, the outputs in the numerator and inputs in the denominator have to be combined in some economically sensible fashion, so that productivity remains the ratio of two scalars. Differences in production technology, scale of operation, operating efficiency and the operating environment in which production occurs are the most common causes of variations in productivity either across producers or through time.

Technical efficiency of a producer is a comparison between observed and optimal values of its outputs and inputs. This can be done either from the output side or input side. On the output side observed output is compared to potential output obtainable from the inputs while from the input angle observed input levels are compared to minimum potential input required to produce the output. In either perspective, the optimum is defined in terms of production possibilities.

It is also possible to define the optimum in terms of the behavioral goal of the producer. In this case, efficiency is measured by comparing observed and optimum cost, subject to any appropriate constraints on quantities and prices. In these comparisons, the optimum is expressed in value terms and efficiency is allocative.

Some authors distinguish other dimensions of efficiency beyond these two (Gonzalez-Vega, 1998; León, 2001; Alpízar, 2007). Gonzalez-Vega (1998), for example, considers five additional categories, describing them in terms of the actions on which production units should embark in order to achieve the greatest possible efficiency:

i) Technological efficiency: to choose the best available technology (production function) to produce each output;
ii) Dynamic efficiency: to promptly absorb innovations in products and processes;
iii) Approach efficiency: to select appropriate technologies according to the nature and magnitude of any challenge faced in the market;
iv) Pure technical efficiency: not to use more inputs than necessary to produce a given amount of output, given the technology;
v) Scale efficiency: to find the correct level of production with the aim of taking advantage of economies of scale; and
vi) Joint-production efficiency: to determine the most attractive combination of output, given the opportunity to generate economies of scope.

It is important to note that the measurement of technical efficiency assumes that the factors of production used are homogeneous. It is not much of a problem if all firms use heterogeneous inputs in fixed proportions. However, if firms are different in the composition of their inputs, according to their quality, then a firm’s technical efficiency will reflect both the quality of its inputs and the efficiency in their management. As a result, if technical efficiency is defined with respect to a given set of firms and a given set of factors of production, measured in a specific way, any differences across firms in the quality of the inputs will affect the measure of efficiency (Farrell, 1957)

2.3 Economic Efficiency

Economic efficiency has two components: technical and allocative efficiency. Technical efficiency refers to the ability to avoid wastage either by producing as much output as technology and input usage allow or by using as little input as required by technology and output production. Technical efficiency has, therefore, both an input conserving and output promoting argument. According to Koopmans (1951), a producer is technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in any input required an increase in at least one other input or reduction in at least one output. Therefore, a technically efficient producer could produce the same output with less of at least one input or could use the same input to produce more of at least one output.

Another definition exits which looks at relative technical efficiency. A producer is fully efficient on the basis of available evidence if and only if the performance of other producers does not show that some inputs or outputs can be improved without worsening some of its other inputs or outputs. With this definition, there is no need for recourse to prices and other assumptions of weights which are supposed to reflect the relative importance of the different inputs and outputs (Cooper *et al.,* 2004). The measurement of technical efficiency is important. According to Alvarez and Arias (2004), technical efficiency reduces production costs and makes a firm more competitive.

The allocative efficiency index measures a production unit's ability to choose the input combination that minimizes cost given the best available technology. It is the ratio between the minimum costs if it were technically efficient. Because allocative efficiency implies substituting or intensifying the use of certain inputs based on their prices, inefficiencies may stem from unobserved prices, from incorrectly perceived price or from lack of accurate and timely information.

2.4 Measurement of Efficiency

Efficiency measurements involve a comparison of actual performance with optimal performance located on relevant frontier. Since the true frontier is unknown, an empirical approximation is required. The approximation is normally called a “best-practice” frontier. Approximation of the best practice frontier can be done using parametric or non parametric techniques. Both techniques put emphasis on optimizing behavior subject to constraints. Berger and Humphrey (1997) identifies at least four different types of approaches (data envelopment analysis, free disposal hull, stochastic frontier approach, and thick frontier approach) that have been employed for determining the best-practice frontier against which relative efficiency scores are measured. However, there is no agreement on which is the best method. The differences in these methods lies in the differences on the assumptions made on:

1. the functional form of the frontier, be it a parametric or a nonparametric functional form;
2. whether a random error is included; and
3. if there is random error, what probability distribution is assumed for the efficiency scores

Data Envelopment Analysis (DEA) is a Non-parametric technique. It builds a linear piece-wise function from empirical observations of inputs and outputs, without assuming any a priori functional relationship between the inputs and outputs. Efficiency measures are then calculated relative to this surface. Testing of hypothesis is not possible and this method does not suffer multicollinearity and heteroscedasticity.

Another non-parametric method of estimation is the Free Disposal Hull (FDH). It is a special case of the DEA model, because it includes only the DEA vertices and the free disposal hull points, interior to these vertices. Thus, the FDH usually generates larger estimates of average efficiency than the DEA. Both approaches allow the variation of efficiency over time and do not impose any a priori functional form to the distribution of inefficiency scores. They do not suffer multicollinearity and heteroscedasticity but testing of hypothesis is not possible.

The Stochastic Frontier Approach (SFA), also referred to as the econometric frontier approach, specifies a functional form for the cost, profit, or production relationship among inputs, outputs, and environmental factors, and it allows for random errors. Another parametric approach is the Distribution-Free Approach (DFA), which also designates a functional form for the frontier, except that it assumes that the efficiency of each firm is stable over time, whereas the random error tends to average out to zero over time.

Finally, the Thick Frontier Approach (TFA) specifies a functional form and it assumes that deviations from the predicted performance values from the highest and lowest performance quartiles of the observations (stratified by size class) represent random error, while deviations in predicted performance between the highest and lowest quartiles represent inefficiency (Berger and Humphrey, 1997). Parametric methods are susceptible to misspecification errors. The advantage is that it becomes possible to test hypotheses.

In recent years both parametric and non parametric methods have become more robust than they were years ago. The exploration of efficiency of small holder farmers using the most recent techniques is left for future research, as for this study; time, data and resource constraints favored convenience and used DEA.

The non parametric method of measuring efficiency was first introduced by Farrell (1957) and many improvements have since been made to his works. Farrell (1957) considered a firm that employs two factors of production X and Y to produce a single product P, under conditions of constant returns to scale. These assumptions make it possible to illustrate the production function by a simple isoquant diagram, designated by *SS'* in Figure 2. This author also assumed that the efficient production function is known; otherwise, it would have to be estimated from sample data by using any of the various methods available.

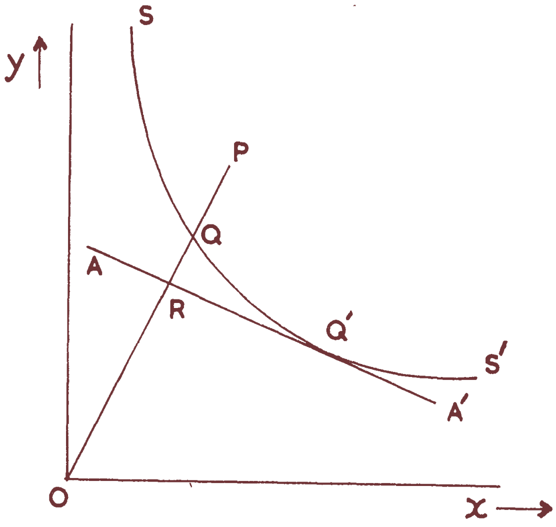

Figure 2: Technical and Allocative efficiency
Source: Ajibefun (2008)

The point P represents the units of two factors, per unit of output that the firm is observed to use. The isoquant ‘SS’ represents various combinations of the two factors that a perfectly efficient firm might us to produce a unit output. It is also important to note that ‘SS’ presents a lower bound of a scatter indicating the same level of output and as such Q and P are on the same isoquant. The point Q represents an efficient firm using the two factors in the same ratio as P. It can be seen that it produces the same output as P using only a fraction OQ/OP as much of each factor. It is producing OP/OQ times as much output from the same inputs. Therefore OQ/OP is defined as the technical efficiency of Firm P. The technical inefficiency of that firm is presented by the distance QP which is the amount by which all inputs could be proportionally reduced without a reduction in outputs. The firm is technically efficient if the ratio is equal to 1. If the ratio is less than 1 the firm is inefficient.

Price or allocative efficiency of the firm can be measured from the same diagram above. This measures the extent to which a firm uses the various factors of production in the best proportions, in view of their prices. Considering the budget line represented by AA**’**, its slope is equal to the ratio of the prices of the two factors of production. Therefore the optimal point is obtained where the isoquant curve is tangential to the budget line and that is point Q**’**. At this point the firm is both technically and allocatively efficient. The allocative efficiency is the fraction OR/OQ

Charnes *et al.* (1978), building on Farrell’s work developed the fractional linear programming method of DEA, the Charnes, Cooper and Rhodes (CCR) DEA model, which compares inefficient firms with the best practice ones within the same group. It assumes constant returns to scale. Bankers et al (1984) added another constraint to the CCR model to reflect variable returns to scale and formed the Banker, Charnes, and Cooper (BCC) DEA model. DEA has been widely used for efficiency studies for both public and private organizations. In agricultural economics, DEA has gained ground with a lot of studies being done.

2.5 Review of Factors influencing Efficiency

Literature suggests many factors which affect the efficiency of farmers. These are classified into conventional and non-conventional factors. Non-conventional factors capture the impacts of macroeconomic variables such as public investment and agro-ecological variables. Conventional factors are traditional choice variables in the farmers’ production decision process. According to Frisvold and Ingram (1994), the conventional inputs include labor intensity, fertilizer usage, tractor use intensity and stock of livestock. On the other hand, non-convectional inputs include land quality, irrigation, agricultural research, calorie availability, agricultural export and instability. Deininger and Olinto (2000) and Pender *et al.* (2004) also identified fertilizer, cattle ownership, access to credit, supply of extension, human capital (education, age, and gender of house head), family size and proportions of dependants as explanatory variables to efficiency. The plot level factors such as the size of the farm, tenure, distance of the field from the residence in one way or another affects productivity (Xu *et al.*, 2009).

Ownership of livestock especially oxen is likely to help framers prepare their fields early and also allows them to increase the area of land cultivated. Furthermore livestock acts as buffer zone and improves farmers' access to credit and fertilizer markets. In an effort to identify strategies to increase agricultural productivity and reduce land degradation, Pender *et al*. (2004) used econometric analysis on cross sectional data in Uganda. The study findings showed that ownership of livestock (especially oxen), agro-climatic zones, primary sources of income, age of house head, ownership of land and participation in agricultural extension activities positively affected productivity. This study also shows that investments such as irrigation facilities are more likely to improve productivity.

Population density has a bearing on the way farmers employ their inputs. Studies show that farmers in high density populated areas tend to use intensive methods of crop production. For example Frisvold and Ingram (1994) and Pender *et al*. (2004) show that households in more densely populated areas were found to adopt some labor intensive land management practices which enabled them to increase crop production per hectare.

Farm size also affects the productivity. Pender et al (2004) showed that farm size was negatively related to productivity in Uganda. In Zambia, Brambilla *et al*. (2009) used cross-sectional post harvest survey data to investigate the dynamic impacts of cotton marketing reforms on farm output. This study showed that small farms are more efficient. Frisvold and Ingram (1994) also agree that for small fields the production is normally small but in terms of productivity or production per hectare they perform better than larger plots.

Trade performance has some impact on the agricultural productivity. If farmers can access local and export markets, literature shows that productivity can go up because whatever is produced would be bought on the market. Using cross section time series data for 28 sub Saharan African countries, Frisvold and Ingram (1994) estimated an aggregate agricultural production function in an attempt to examine sources of agricultural productivity growth and stagnation. The results showed that the coefficient on agricultural export was positive and statistically significant. However, Pender *et al.* (2004) found little evidence on the impact of access to markets on agricultural intensification and crop productivity. The explanation to this could be that Pender *et al*. (2004) used sectional data while Frisvold and Ingram (1994) used panel data.

Although education as human capital is important for increasing household income, it was not found to be a solution to the problem of low productivity in Uganda (Pender *et al.*, 2004). Similar results were reported by Deininger and Olinto (2000) using panel data of the post harvest survey. However, the study which aimed at examining the relatively lackluster performance of the country's agricultural sector following liberalization concluded that education enables farmers to overcome market imperfections as reflected in the fact that more educated farmers demand higher amounts of fertilizer and credit per hectare.

2.6 Related Studies on Efficiency using Parametric Methods

Various studies have been conducted on technical efficiency using the stochastic frontier. For example Siregar and Sumaryanto (2003) determined technical efficiency in Brantas river basin in Indonesia. The research showed that technical efficiency of soybeans production in the sites was high around 83 per cent. However analysis failed to identify determinants of technical efficiency because none of the parameters in the study was significant.

Amos (2007) looked at the productivity and technical efficiency of small holder cocoa farmers in Nigeria. Farmers were observed to be experiencing increasing returns to scale. The efficiency levels ranged between 0.11 and 0.91 with a mean of 0.72. This indicates that there is plenty of room for farmers to improve their efficiency. The major contributing factors to efficiency were age of farmers, level of the education of household head and family size.

A study conducted in Malawi revealed similar results. Chirwa (2007) focused on the sources of technical efficiency among small scale farmers in southern Malawi. Econometric results showed that many smallholder maize farmers are technically inefficient, with mean technical efficiency scores of 46 per cent and technical scores as low as 8per cent. The mean efficiency levels were lower but comparable to those obtained in other African countries whose means range from 55 per cent to 79 per cent. The results also support the hypotheses that technical efficiency increases with the use of hybrid seeds and club membership. One of the variables used for capturing adoption of technology showed that the application of fertilizers does not explain the variations in technical inefficiency. This may imply that most farmers using these technologies use them inappropriately on small land holdings

In examining the technical efficiency of alternative land tenure systems among smallholder farmers, Kuriuki *et al (*2008) conducted a study in Kenya to identify determinants of inefficiency with the objective of exploring land tenure policies that would enhance efficiency in production. The study was based on the understanding that land tenure alone was not enough to indicate the levels of efficiency of individual farms. Other socio economic factors such as gender, education and farm size were expected to be important determinants of efficiency. The study found that parcels with land titles have a higher efficiency level. Other factors such as education status of head, access to fertilizers, and group participation were also found to significantly influence technical efficiency.

2.7 Related Studies on Efficiency using Non Parametric Methods

Non parametric methods of determining efficiency have been used in many countries. For instance, Helfand and Levine (2000) explored the determinants of technical efficiency and the relationship between farm size and efficiency, in the Center-West of

Brazil. The efficiency measures were regressed on a set of explanatory variables which included farm size, type of land tenure, composition of output, access to institutions and indicators of technology and input usage. The relationship between farm size and efficiency was found to be non-linear. Efficiency was first falling and then started rising with farm size. The type of land tenure, access to institutions and markets, and modern inputs were found to be important determinants of the differences in efficiency across farms.

Rios and Shively (2005) also looked at the relationship between farm size and efficiency. They focused on the efficiency of smallholder coffee farms in Vietnam on which the two stage analysis approach was used. In the first step, technical and cost efficiency measures are calculated using DEA. In the second step, Tobit regression was used to identify factors correlated with technical and cost inefficiency. Results indicated that small farms were less efficient than large farms and inefficiencies observed on small farms appeared to be related, in part, to the scale of investments in irrigation infrastructure.

Shafiq and Rehman (2000) studied the extent of resource inefficiencies in cotton production in Pakistan’s Punjab. The study identified significant levels of both technical and allocative efficiency. However both the interpretation of the farm level results generated and the projection of the results to a higher level require care because of the technical nature of the agricultural production process.

Fletschner and Zepeda (2002) determined efficiency levels at a higher level. They looked at efficiency at regional and national levels. Three regions were selected to represent distinct production system and social economic conditions. The results indicated high level of technical efficiency across the region but low levels of allocative and scale efficiency. Factors affecting efficiencies included employment opportunities, access to credit, market and extension services.

From the above literature is clear that DEA has gained considerable ground in Agricultural Economics. Most studies using non parametric methods have focused on other agricultural crops but not maize which is an important crop for most African countries. The few studies that have looked at maize only looked at technical efficiency and not allocative efficiency.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter begins with a briefly discussion of DEA followed by the mathematical linear programming model used to estimate the efficiency scores. It then goes on to discuss the regression model used to identify factors influencing efficiency and the anticipated relationships. Finally it gives a detailed presentation of the data and sampling procedures used in the collection of data being used in this study.

3.2 Methods

This study used a two step procedure of analysis (Banker and Natarajan, 2008; Fletschner and Zepeda, 2002). Firstly, the Generalized Algebraic Modeling System (GAMS) software was used to solve the DEA problem and generate the technical efficiency indices for each of the smallholder maize farmers in the sample. Secondly, the indices obtained were regressed on identified farm and household characteristics.

3.2.1 Data Envelopment Analysis

Data Envelopment Analysis (DEA) was developed mainly based on Farrell's work (Farrell, 1957). In DEA the production of an efficiency frontier is based on the concept of Pareto optimum. The Decision Making Units (DMUs) that lie on the efficient frontier are non-dominated and thus called Pareto optimal units or efficient DMUs. They are assigned an efficient index of one, while those that do not lie on the efficiency frontier are regarded as relatively inefficient with positive efficiency indices of less than one.

DEA has the advantage of determining efficiency in multiple input-multiple output scenarios. Its first task is to determine which of the DMUs, as represented by observed data, form an empirical production function envelopment surface which is referred to as the efficiency frontier (Ajibefun, 2008). Thereafter, DEA provides a comprehensive analysis of relative efficiency by evaluating each DMU and measuring its performance relative to the envelopment surface.

This study will use the Banker, Charnes and Cooper DEA model for both technical and allocative efficiency. This model assumes variable returns to scale. Efficiency can be estimated from the output side where a DMU produces maximum output given a level of inputs and from the input side where a DMU uses the minimum level of inputs to produce a given level of output. The findings from either side should be same. This study opts to use the input orientation. The logic is to estimate the minimum amounts of inputs that can be used to produce a given level of output. According to Fletschner and Zepeda (2002), technical efficiency for production unit h (TE^h), is found by comparing unit h with combinations of all other production units and establishing the minimum proportion of inputs that would allow unit h to produce the level of output actually being produced by h. Each household's technical efficiency is derived from a separate problem because each household faces a different set of constraints. However, given that each household is independent, the Z efficiency measures can be calculated as a single problem. It is possible to aggregate the constraints and replace the objective function with one minimizing the sum of the technical efficiency coefficients (TE^h). Minimizing the sum of the coefficients ensures that each household‘s coefficient is also minimized. When the household' coefficient is minimized the households optimal level of inputs is also minimized. The mathematical linear programming problem used to measure technical efficiency is given as:

$$\min \sum_{h=1}^{z} TE^{h} \tag{1}$$

$$st: \sum_{t=1}^{z} \lambda_t^h y_s^t \geq y_s^h \qquad \text{for s=1,.....,m;h=1,.....,z}$$

$$\sum_{t=1}^{z} \lambda_t^h x_g^t \leq TE^h x_g^h \qquad \text{for g=1,.....,n;h=1,.....,z}$$

$$\sum_{t=1}^{z} \lambda_t^h = 1 \qquad \text{for h=1,.....,z}$$

$$\lambda_t^h \geq 0 \qquad \text{for t=1,.....,z;h=1,.....,z}$$

$$TE^h \geq 0$$

Source: Fletschner and Zepeda (2002)

Where there are m outputs and n variable inputs, y_s^h is the sth output of unit h, and x_g^h is the gth variable input of unit h. The combination of units against which unit h is compared is given by the vector λ^h .Where each element in the vector is the weight of each of the Z units in combination. The weighted outputs and inputs of those units against which unit h is compared are given by $\sum_t \lambda_t^h y_s^t$ and $\sum_t \lambda_t^h x_g^t$ respectively. Where y_s^t denotes production of outputs for each of the t =1,…., z units and x_g^t denotes the endowments of inputs for each of the t =1,….,z units. The first set of constraints warrants that for each output the amount produced by the combination of production units is at least as much as unit h's output. The second group of constraints requires that combining productions units in the same manner, the variable inputs used should not exceed units *h's* variable inputs. There are *n* variable inputs. The third constraint guarantees unit *h's* production frontier is weakly concave. This represents viable returns to scale. The main inputs used in maize production are seed, fertilizer, land and labour. Land was measured in hectares. Fertilizer was measured in kilograms and constitutes both top and basal dressing fertilizers. Seed was also measured in kilograms. Age and sex of family members was used to calculate adult equivalents which were used as estimates for labour. Quantity of maize harvested was measured in kilograms. The four inputs plus output were used to generate the efficiency indices using GAMS software.

To measure allocative efficiency it is necessary to find the minimum cost, given input prices, output, and levels of technology. The minimum costs for each DMU are obtained using the following linear programming problem.

$$\min_{x^*,\lambda^h} \sum_{h=1}^{z} w^h x^{*h} \tag{2}$$

$$st: \sum_{t=1}^{z} \lambda_t^h y_s^t \geq y_s^h \qquad \text{for s=1,.....,m;h=1,.....,z}$$

$$\sum_{t=1}^{z} \lambda_t^h x_g^t \leq x_g^{*h} \qquad \text{for g=1,.....,n;h=1,.....,z}$$

$$\sum_{t=1}^{z} \lambda_{\mathrm{t}}^{\mathrm{h}} = 1 \qquad \text{for h=1,.....,z}$$

$$\lambda_{\mathrm{t}}^{\mathrm{h}} \geq 0 \qquad \text{for t=1,.....,z;h=1,.....,z}$$

Source: Fletschner and Zepeda (2002)

Having obtained the minimum cost for each of the z households, the allocative efficiency measure for the household *h* (AE^h) is given by the ratio of the minimum cost above and farm *h*'s costs if they had been technically efficient as follows:.

$$AE^h = \frac{w^h x^h}{w^h x^*} \tag{3}$$

Where w^h is an n-vector of inputs prices, x^{*h} is the least-cost variable input combination for household h, and $w^h x^{*h}$ is the minimum cost that would allow household h to produce the same output level given the available technology.

3.2.2 Regression Model

The efficiency indices determined by the mathematical programming models were regressed on farm and farmer characteristics in order to identify sources of technical and allocative efficiency. The efficiency indices from DEA usually result into a censored variable. That is, the efficiency variable, though continuous with values between 0 and 1, would be censored at 1 (for all farmers considered efficient) and at zero (for all those considered inefficient). However, results from the first stage showed that only about 60 (1.18 percent) and 17(0.33 percent) of the 5,169 observations were fully technically and allocatively efficient and hence censored. Because of the negligible level of censoring a linear estimator was preferred. After checking and ensuring that all the assumptions of a classical linear regression model are upheld, Ordinarily Least Squares (OLS) was selected as the most efficient estimator.

$$y_i = x_i\beta + u_i \tag{4}$$

where y_i represents the efficiency scores, and x_i represents farm and farmer specific characteristics. $u|x_i$ are independently distributed with zero means, $0 \le y_i \le 1$, with limit point $y_i = 1$ possessing positive probability. $y_i = 1$ means that the maize farmer is technically or allocatively efficient and where $0 \le y_i \le 1$, the maize farmers is inefficient.

From literature, various factors have been identified to influence efficiency. Pendal *et al.* observed that fertilizer use, cattle ownership, access to credit, supply of extension, human capital (education, age, and gender of house head), family size, agro- climatic zones, primary sources of income, ownership of land and participation in agricultural extension activities affected productivity in one way or the other affected the efficiency of farming households. Farm plot level factors such as the size of the farm, tenure, distance of the field from the residence were seen to be other factors influencing the efficiency of farmers (Xu *et al*., 2009). Out of the many factors listed above only a few were used due to the limitation of the data set. The characteristics include the age, education attained and sex of the head who is the key decision maker in the household. Family size, tillage method employed by the household, Average rainfall, the type of seed, access to extension services, involvement in community agricultural activities, ownership of livestock, use of organic fertilizers and the size of the field are other characteristics used to explain the observed inefficiencies.

The age of a household is used as a proxy for farming experience. It is therefore included to evaluate the effect of age on the level of technical and allocative efficiency among maize farmers. According to Shafiq and Rehman (2000), age of a farmer is expected to have a positive or a negative relationship with efficiency of the farm. This means that older farmers can be more experienced and efficient in doing their farm operations. It was further highlighted by Shafiq and Rehman (2000) that it is possible that older farmers may be traditional and conservative and show less willingness to adopt new farming technology and hence could be less efficient. The sign could be either positive or negative.

Gender is an important determinant in efficiency. The relationship between technical and allocative efficiency is likely to be negative and positive respectively. Male households are likely to be wealthier and able to adopt new and expensive agricultural technologies. On the other hand female farmers are more likely to attend meetings and adopt the best production practices.

Education is used as a proxy for human capital. It is expected to be positively related to efficiency. It is known that higher level of education may lead to better management of farming activities. This is because educated farmers are likely to access information easily, and use it to make well informed decisions. Furthermore farmers with more education have been shown to adopt modern agricultural technologies sooner (Feder *et al*., 1985).

Household size can influence the efficiency of the farm in the positive or negative sense. Households with relatively fewer members could, on one hand, be fully exploiting the available labour and hence being more efficient or could be facing labour constraints on the other, and this makes them unable to adopt labour intensive technologies which may be efficiency enhancing.

Tillage systems are also important factors in influencing efficiency at the farm. There are conservation and conventional tillage systems. In this study, the conservation tillage system includes planting basins, ripping and zero tillage. While the conventional tillage systems are ploughing, hand hoe, ridges and bunding. We suppose conservation tillage systems to have a positive sign while the conventional tillage systems to have a negative sign. Time of tillage is another variable considered. Farmers who till the land after the rains are expected to have lower efficiency levels. Such farmers are likely to plant late or pay more for hired labour as labour cost increase with the rains.

Seed type is also an important factor in determining the efficiency of maize farmers. In this study seed was divided into three categories: certified hybrid seed, Open Pollinated varieties (OPVs) and recycled hybrid and local varieties. Farmers who use certified hybrid seed are projected to have higher efficiency levels. The sign on the two seed dummies: OPVs and recycled hybrid and local varieties are expected to be negative.

Maize is a crop that needs a lot of nitrogen especially if certified hybrids are used. Fertilizer use is therefore an important determinant of efficiency. Farmers who use fertilizers are expected to have higher efficiency scores. The sign for non use of fertilizer is expected to be negative,

Farmers who access extension services or are active in agricultural activities (attending agricultural meetings, field day and demonstration plots) are anticipated to have easier access to market information and best available practices. The sign on the coefficient for no access to extension and non involvement in agricultural activities is expected to be negative. Lastly farmers who own livestock are expected to have higher efficiency levels. The sign on the coefficient for non ownership of livestock is expected to be negative.

3.2.3 Regression Diagnostics

Regression Diagnostics were done for both the technical and allocative efficiency models to ensure that the available data meets the assumption underling OLS regression. Firstly the linearity assumption was checked to see if the relationships between the predictors and the outcome variable are linear. Augmented component-plus-residual plots (acprplot) and scatter plots were used to check for linearity. Plots were done for the four continuous variables in the data set, farm size and household size, rainfall and years of schooling. The results suggested some departure from linearity except for years of schooling. The three problem variables and the dependent variables were transformed into log form and this resolved the linearity problem between efficiency and age and household size. Farm size still continued exhibiting some departure from linearity and hence a square term was included to account for the observed quadratic nature of the relationship between farm size and efficiency.

The data was also tested for multicollinearity. It is expected that no single regressor should be a linear function of another. The variance inflation factor (VIF) was used in Stata and the results showed no problems of multicollinearity except for two variables. These are rainfall data and district dummies. This multicollinearity was anticipated because the rainfall was collected at district level. Both variables are trying for control for differences among districts. This has resulted in the rain fall variable and some district dummies having VIF s greater than 10.Multicollinearity in these variables was expected as the rainfall data is was collected at district level while log farm size squared is a multiple of log farm size. Despite the high values of VIF among the problem variables, the average VIF stands at 4.33.

Heteroskedasticity is a violation of one of the requirements of ordinary least squares (OLS) in which errors variance is not constant (Wooldridge, 2004; Green, 2002;

Gujarati, 2004; Maddala, 2002). The consequences of heteroskedasticity are that the estimated coefficients are unbiased but inefficient. The variances are either too small or too large, leading to Type I or II errors under heteroskedasticity. OLS is not BLUE (Best Linear Unbiased Estimator). Some of the main causes of heteroskedasticity are 1) variance of dependent variables increase in the level of dependent variable. 2) Variance of dependent increases or decreases with changes in dependent variables, 3) Outliers, 4) Trends in learning or uncertainty and 5) Specification bias (missing variables or incorrect functional form. Heteroskedasticity is mainly common in cross-sectional data set such as the one used in this data. A test for heteroskedasticity was done to verify the assumption of constant variance. The Breusch-Pagan/Cook-Weisberg test for heteroscedasticity was used. The null hypothesis is that there is no heteroscedasticity. The test was significant at one percent suggesting that the data has heteroscedasticity since we reject the hull hypothesis. To correct for heteroscedasticity, the robust option was used in the OLS regressions for both models (Baum, 2006).

The normality assumption was checked using a kernel density plot. Normality of residuals is important for valid hypothesis testing, that is, the normality assumption assures that the p-values for the t-tests and F-test are valid. The kernel density plot for the technical efficiency showed no indication of any departure from a normal distribution. The plot from the allocative efficiency showed a generally normal pattern.

3.3Data and Sampling Procedures

Secondary data from cross-sectional household surveys (Crop Forecasting and Post Harvest Surveys) conducted by Central Statistical Office (CSO) was used. The crop forecasting survey captures information on farmer s' access to particular services such as extension, credit, and marketing channels. The post harvest survey collects detailed information on inputs and outputs for various crop enterprises. A stratified two-stage sample design is used in these surveys. The Primary Sampling Units (PSUs) are one or more Standard Enumeration Areas (SEAs) with a minimum of 30 agricultural households. In the first stage the CSO tries to ensure that each district is allocated a minimum of two sample SEAs and therefore, sample SEAs are stratified by district. Within each district, the frame of SEAs is ordered by certain characteristics to provide further implicit stratification when the sample is selected systematically with probability proportional to size (PPS). The first sorting is by the rural and urban region variable. The second stratification is by crops predominantly grown by most households in each SEA. This is done to improve the precision of the survey estimates of crop area and production. Eight crops which receive special treatment in the sample design are sorghum, rice, cotton, Burley tobacco, Virginia tobacco, sunflower, soybeans and paprika.

Following the ordering of the frame by rural/urban and crop stratum codes, the SEAs in the frame for each district are sorted by all the hierarchical geographic codes below the district level: constituency, ward, CSA and SEA. This ensures that the geographical distribution of the sample SEAs is representative. Proportional allocation of SEAs is as follows: The smallest Province (Lusaka) is allocated a minimum of 24 sample SEAs and the largest Provinces (Eastern and Northern) are allocated a maximum of 72 sample SEAs.

At the second sampling stage, a listing of households is used to stratify the households by farm size, number of livestock and the growing of special crops within each sample SEA. Category A consist of households with farm sizes less than 2 hectares while category B includes farm size 2hectares and above but less than 5 hectares, and category C consists farm size 5 hectares and above but less than 20 hectares. Category C households are generally included in the sample with certainty (up to 10 households), and the Category B households are selected with a higher probability than the Category A households. Any farms with a large number of livestock or poultry are added to Category C (if they do not qualify based on land area). The sample households are then selected from the listing stratified by farm size category for each category in an SEA. A specified number of sample agricultural households are selected systematically with a random start. Twenty households are allocated to the three categories within each sample SEA.

The study used data from the Post Harvest Survey (PHS) and Crop Forecasting Survey (CFS) for the 2005/2006 cropping season. More of the farm and farmer characteristics suggested to influence efficiency were captured in this year compared to other years especially the more recent surveys. Only maize farmers were considered from this survey. In this year 5,196 smallholder maize farmers were captured. Input prices were obtained from the Agriculture Marketing information Center (AMIC) a branch under the Ministry of Agriculture and Cooperatives. The centre collects prices on a monthly basis, on price of agricultural inputs and products. Shadow prices for land and labour were obtained from the 2004 Supplemental survey to the 1990 Post Harvest Survey conducted by Food Security Research Project (FSRP).

3.4 Limitations

This study depended on data from the 2005/2006 Post Harvest and Crop Forecasting surveys for input and output quantities as well as the farm and farmer characteristics. While very comprehensive in relation to surveys from other years, both these data sources were also inadequate in a number of respects. Firstly the dataset was limited in farmer and farm characteristics suggested to influence efficiency as revealed in past literature. The study used only what was contained in the literature. Secondly input prices were not easily available. Fertilizer and seed prices were only available at provincial level and not district level. Price for land and labour were not available and hence average shadow prices were used instead.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This Chapter begins with a discussion on farm and farmer characteristics inherent among small scale farmers included in the study. An analysis of technical and allocative efficiency at national and provincial level is done together with the distribution of the efficiency scores across the various farm and farmer characteristics included in the study. Finally the determinants of efficiency are discussed in detail.

4.2 Farm and Farmers' Characteristics

Farm and farmer characteristics are summarized in Table 1. More than half (55 per cent) of the farmers captured in the survey ended their education at primary level and 14 percent of the farmers have never been to school. Eighty-two percent of the households were headed by males. Farmers' age ranged between 19 and 90 years. The average age was 45 years, with 75 per cent of the farmers being 55 years old and younger. These farming households had an average household size of 7. Most of the farming households actually had 5 to 7 members with about a quarter of the respondents having small families with 1 to 4 members.

Conventional hand hoeing was the most frequently used tillage method at 36 percent followed by ploughing at 34 percent and ridging at 21 percent. More than half (68%) of the farmers in the survey ploughed their fields after the rains and only 6 percent and 43 percent applied manure and inorganic fertilizer respectively. Six percent used both organic and inorganic fertilizers. The majority of the farmers used local and recycled hybrid (63%) and 36 percent of the farmers used certified hybrid seed. Average seed rate was 34kgs per hectare while average rate of fertilizer application is 265kgs per hectare which constitutes both basal and top dressing fertilizers. Average farm size is at 1.29 hectares and average yield is 2.4 mt per hectare

Table 1: Farm and Farmers Characteristics

Variable	Units	Mean	Std. Dev	Min	Max
Fertilizer used	kg/ha	265	198	1	3200
Annual Rainfall	mm	772	171	410	1175
Yield harvested	kg/ha	2430	1602	7	12978
Seed used	kg/ha	34	89	1	2736
Labour used	Adult equiv	5.24	2.44	0.72	17.68
Tillage before the rains	1=yes, 0=no	0.32	0.47	0.00	1.00
Used manure	1=yes, 0=no	0.06	0.24	0.00	1.00
Used certified hybrid seed	1=yes, 0=no	0.36	0.48	0.00	1.00
Age of household head	1=yes, 0=no	45.26	14.67	19.00	90.00
Male household head	1=yes, 0=no	0.82	0.38	0.00	1.00
Household size	members	6.60	3.01	1.00	23.00
Owns livestock	1=yes, 0=no	0.32	0.47	0.00	1.00
Accessed extension services	1=yes, 0=no	0.06	0.24	0.00	1.00
Active in agric actives	1=yes, 0=no	0.28	0.45	0.00	1.00
Used chemical fertilizer	1=yes, 0=no	0.43	0.50	0.00	1.00
Dummies for Age Groups					
0 to 25 years	1=yes, 0=no	0.06	0.23	0.00	1.00
26 to 55 years	1=yes, 0=no	0.69	0.46	0.00	1.00
56 and older years	1=yes, 0=no	0.25	0.43	0.00	1.00
Education	years	6.19	3.94	0.00	18.00
Dummies for Education Attainment					
None	1=yes, 0=no	0.14	0.34	0.00	1.00
Primary	1=yes, 0=no	0.55	0.50	0.00	1.00
Secondary	1=yes, 0=no	0.28	0.45	0.00	1.00
college	1=yes, 0=no	0.04	0.19	0.00	1.00
University	1=yes, 0=no	0.00	0.07	0.00	1.00
Dummies for Tillage methods					
Conventional hand hoeing	1=yes, 0=no	0.36	0.48	0.00	1.00
Planting basins	1=yes, 0=no	0.03	0.16	0.00	1.00
Zero tillage	1=yes, 0=no	0.04	0.19	0.00	1.00
Ploughing	1=yes, 0=no	0.34	0.48	0.00	1.00
Ripping	1=yes, 0=no	0.00	0.06	0.00	1.00
Ridging	1=yes, 0=no	0.21	0.41	0.00	1.00
Bunding	1=yes, 0=no	0.01	0.11	0.00	1.00
Farm Size	ha	1.29	1.63	0.06	19.00

Source: Zambia Central Statistic Office 2005/6 Post Harvest Survey

4.3 Technical and Allocative Efficiency Indices

The results showed that out of 5,169 farmers, only 61 farmers were technically fully efficient and 17 were allocatively fully efficient relative to all other farmers. These farmers used and spent far less to produce a unit of output compared to their counterparts who had been deemed inefficient. The national mean technical and allocative efficiency scores were 30 percent and 12 percent respectively (Table 2). These results are much lower than those revealed by Kibaara (2005) in Kenya where technical efficiency was 49 percent and Chirwa (2007) in Malawi where technical efficiency was at 46 percent. This suggests tremendous opportunity to improve technical and allocative efficiency among the farmers. On average, inputs used to produce a given unit of output could be reduced by 70 per cent and production costs by 88 per cent without affecting output.

Table 2: Mean, Max, Min Efficiency Scores and Percentage of Efficient Farmers by Provinces

	Technical Efficiency				Allocative Efficiency			
Province	**Mean**	**Max**	**Min**	**% of efficient farmers**	**Mean**	**Max**	**Min**	**% of efficient farmers**
Central	0.317	1.000	0.098	1.744	0.116	1.000	0.003	0.580
Copperbelt	0.328	1.000	0.080	1.878	0.102	1.000	0.011	0.470
Eastern	0.296	1.000	0.088	0.947	0.106	1.000	0.002	0.079
Luapula	0.317	1.000	0.143	0.513	0.131	0.966	0.015	0.000
Lusaka	0.303	1.000	0.079	0.881	0.103	1.000	0.008	0.440
Northern	0.338	1.000	0.084	0.997	0.121	1.000	0.009	0.500
N/ western	0.277	0.720	0.091	0.000	0.110	0.417	0.001	0.000
Southern	0.293	1.000	0.076	1.894	0.119	1.000	0.002	0.677
Western	0.275	1.000	0.071	0.913	0.129	0.868	0.009	0.000
Total	0.304	1.000	0.071	1.180	0.120	1.000	0.001	0.330

Focusing on the mean efficiency levels by provinces; indicated that some provinces had higher efficiency scores than others (Table 2). From the maximum scores it was observed that North-Western is the only province with neither a technically nor an allocatively fully efficient farmer. Luapula and Western Provinces have some technically efficient farmers but not any allocatively efficient farmers. In terms of mean technical efficiency, Northern Province had the highest level of efficiency followed by Copperbelt and Central Province with Western Province being the lowest. A technically efficient farmer is not necessarily an allocatively efficient farmer as could be seen by the reverse in efficiency levels across provinces. Western province which had the lowest technical efficiency levels had the second highest allocative efficiency levels after Luapula Province. Copperbelt province which was doing better technically had the lowest allocative efficiency levels. Of the total sample of farmers in this study, only 1.18 percent were technically efficient and 0.33 percent were allocatively efficient. Southern Province had the largest proportion of both technically and allocatively efficient farmers.

Cumulative percentage plots (Figure 3) were drawn to see the distribution of the efficiency scores across the sample population. The majority of farmers had efficiency scores below 25 percent's for both technical and allocative efficiency. In terms of technical efficiency, half the population was 28 percent and less as efficient as the fully efficient and 75 percent of the population was 38 percent and less relatively efficient. Just 10 percent of the farmers were 50 percent or more as efficient as the fully efficient farmers while only 3 percent of them were 75 percent and more as efficient as the fully efficient farmers. Allocatively, half of the population was eight percent and less relatively efficient with 75 percent of the farmers being relatively efficient by 13 percent or less. Barely two percent of the farmers were seen to have relative allocative efficiencies greater than 50 percent.

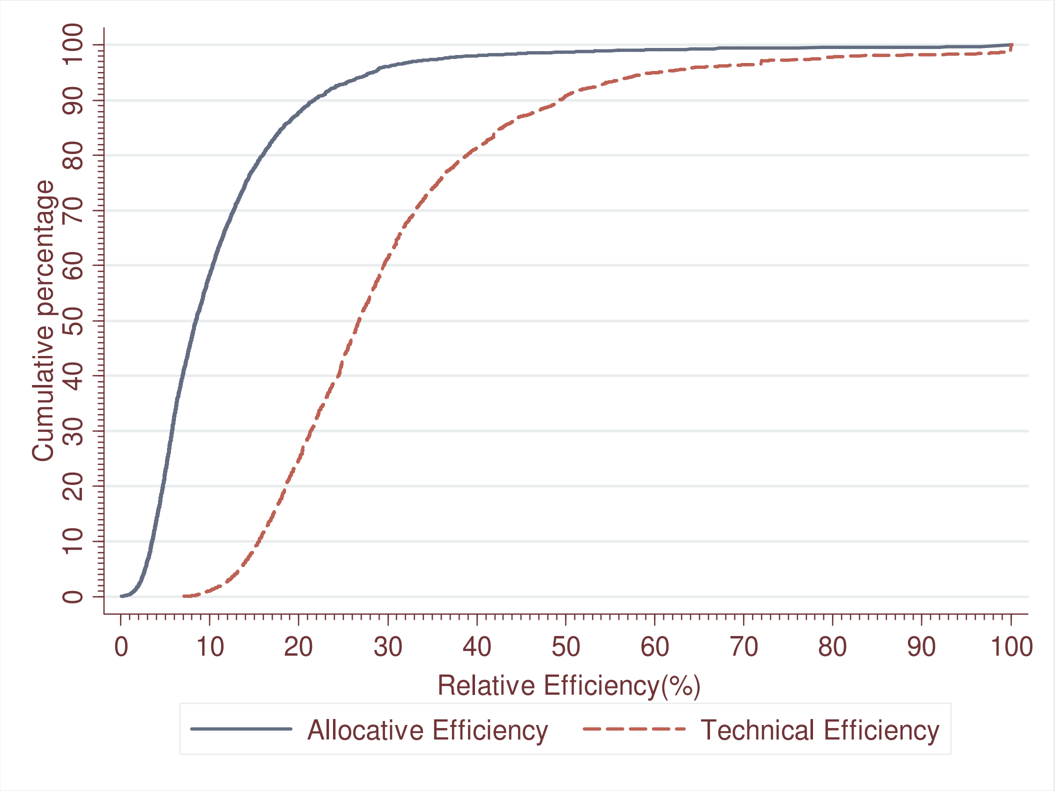

Figure 3: Cumulative Percentage of relative Technical and Allocative efficiency

Beyond comparing the average efficiency of farmers across provinces, there was an interest to compare the mean efficiencies of farmers in similar groups across provinces. This was done to see how farmers in similar proportions of the provincial population compare across provinces. It is possible for a province to generally appear more efficient than others because farmers in one group are the most efficient and yet farmers in other groups are the most inefficient. In light of this, Technical and Allocative efficiency scores were grouped into quartiles (4 equal groups) in each Province depending on their relative performance in that province. Quartile one consisted of farmers who were the least efficient in that province while quartile four consisted of farmers who were the most efficient in the province. Comparisons were done within quartiles across provinces. Figures 4 and 5 display the distribution of technical and allocative mean efficiency scores for all the Provinces according to quartiles. Under technical efficiency quartiles, Western Province had the lowest mean scores for the first and second quartiles meaning that the first half of farmers in Western Province had efficiency levels that were lower than the first 50 percent of farmers from all the other Provinces. Northern Province had a highest provincial mean efficiency even when Southern Province has the highest mean for farmers in quartile four because it has higher mean efficiency scores in all the quartiles except for quartile four. The first 75 percent of the farmer population in Northern Province are more efficient than the first 75 percent of the farmer population in Southern Province.

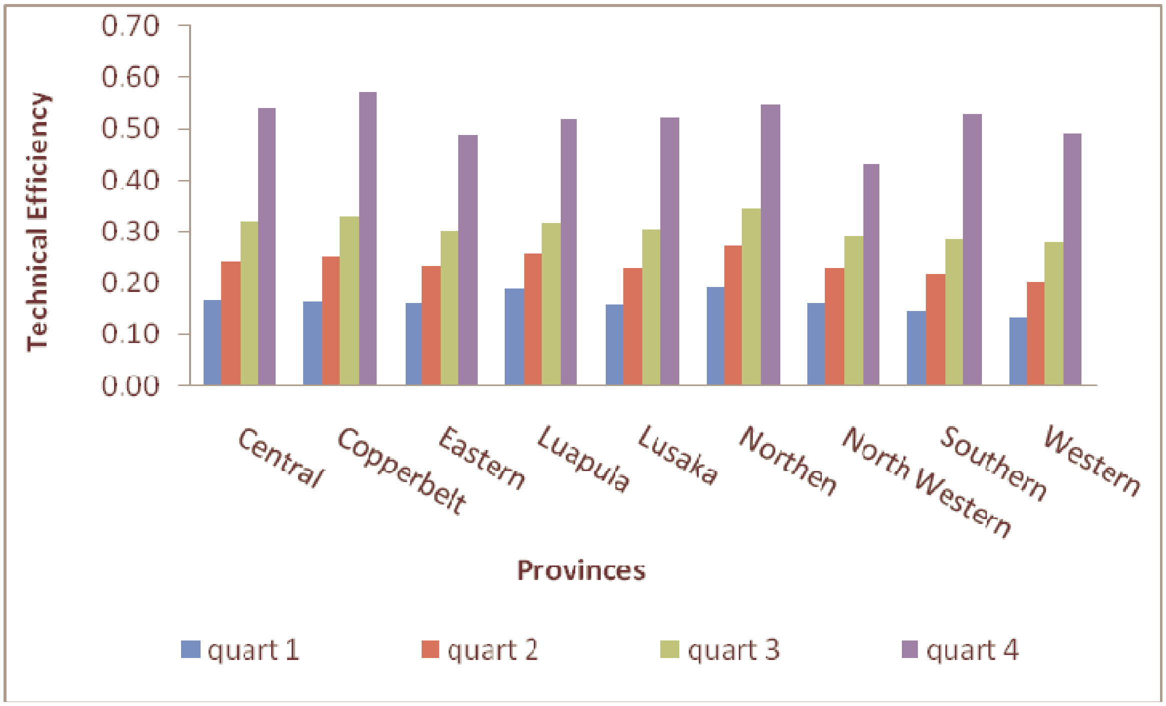

Figure 4: Mean Technical Efficiency across quartiles for each Province

Allocatively, Luapula Province despite not having any fully efficient farmers had the highest provincial allocative mean score. Furthermore, across the four quartiles it had the highest score only in the fourth quartile and it was this high value which was responsible for the high provincial score. Copper belt and Southern Provinces had the lowest allocative mean scores in the first quartile. Among the least efficient farmers, or farmers in quartile one, farmers from Copperbelt and Southern Provinces were the most inefficient.

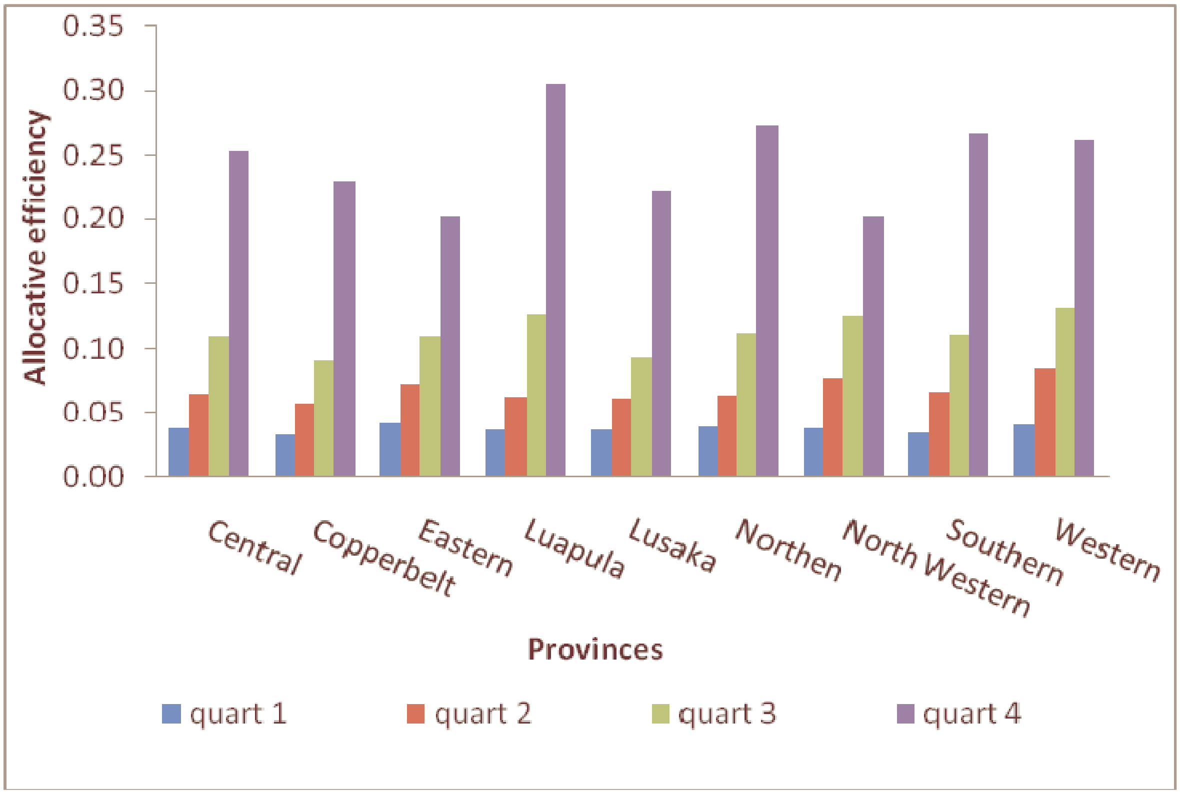

Figure 5: Mean Allocative Efficiency across quartiles for each Province

A comparison of farm and farmers characteristic was done to explore the distribution of the technical and allocative efficiency score across farmer and farm specific characteristic. For technical efficiency, Table 3 shows that out of the seven tillage methods used by farmers, quartile four consists of larger proportions of farmers who ripped and ploughed their land compared to the other quartiles. Larger proportions of farmers who used ridges and zero tillage are found in quartile one. There is a larger proportion of farmers in quartile four who used certified hybrid seed and a larger proportion of farmers in quartile one who used local/recycled hybrid seed compared to other quartiles. Quartile four is further observed to consist of larger proportions of farmers who own livestock, used extension services and chemical fertilizers.

Table 3: Farm and Farmers Characteristic by quartiles of Technical Efficiency

	Technical Efficiency quartiles			
Variable	**1**	**2**	**3**	**4**
Dummies for tillage methods				
Rainfall	766.410	775.412	778.745	768.801
Conventional hand hoeing	0.330	0.349	0.373	0.34268
Planting basins	0.025	0.028	0.027	0.0257
Zero tillage	0.040	0.042	0.041	0.03115
Ploughing	0.362	0.343	0.350	0.3715
Ripping	0.004	0.002	0.003	0.00779
Ridging	0.227	0.221	0.193	0.20872
Bunding	0.013	0.015	0.013	0.01246
Land tillage before the rains	0.335	0.337	0.322	0.30607
Used manure	0.068	0.076	0.053	0.05997
Used OPVs	0.006	0.008	0.005	0.00312
Used certified hybrid	0.341	0.355	0.346	0.39174
Used local/recycled hybrid seed	0.653	0.637	0.648	0.60514
Dummies for Education levels				
Primary	0.580	0.527	0.557	0.51713
Secondary	0.246	0.290	0.274	0.29751
College	0.035	0.043	0.031	0.03816
University	0.003	0.002	0.004	0.01012
None	0.136	0.137	0.133	0.13707
Dummy for age groups				
0 to 25 years	0.012	0.043	0.076	0.09735
26 to 55 years	0.711	0.725	0.709	0.63006
56 and older years	0.277	0.232	0.215	0.27259
Male household head	0.852	0.848	0.797	0.78037
Association	0.298	0.283	0.277	0.26812
Accessed extension services	0.064	0.062	0.050	0.07171
Used chemical fertilizer	0.376	0.426	0.443	0.47274
Owns livestock	0.719	0.710	0.646	0.63835

In terms of Allocative efficiency, a comparison of farm and farmers characteristic in Table 4 shows a reverse picture for ploughing and conventional hand hoeing. Ploughing is now the most used by farmers falling in the first quartile and conventional

Table 4: Farm and Farmers Characteristics by quartiles of Allocative Efficiency

	Allocative Efficiency quartiles			
Variable	**1**	**2**	**3**	**4**
Dummies for tillage methods				
Rainfall	784.486	776.355	765.359	763.081
Conventional hand hoeing	0.294	0.340	0.374	0.387
Planting basins	0.026	0.025	0.031	0.023
Zero tillage	0.032	0.035	0.042	0.046
Ploughing	0.385	0.358	0.340	0.344
Ripping	0.002	0.003	0.005	0.006
Ridging	0.253	0.227	0.192	0.178
Bunding	0.008	0.012	0.017	0.016
Land tillage before the rains	0.310	0.321	0.347	0.323
Used manure	0.063	0.077	0.060	0.057
Used OPVs	0.005	0.006	0.007	0.004
Used certified hybrid	0.464	0.404	0.291	0.272
Used local/recycled hybrid seed	0.531	0.590	0.702	0.724
Dummies for Education levels				
Primary	0.512	0.536	0.563	0.571
Secondary	0.316	0.281	0.255	0.255
College	0.065	0.045	0.024	0.014
University	0.005	0.005	0.003	0.007
None	0.103	0.133	0.155	0.153
Dummy for age groups				
0 to 25 years	0.032	0.053	0.063	0.079
26 to 55 years	0.696	0.703	0.699	0.679
56 and older years	0.272	0.244	0.239	0.242
Male household head	0.851	0.831	0.810	0.786
Association	0.308	0.316	0.277	0.224
Accessed extension services	0.083	0.057	0.059	0.048
Used chemical fertilizer	0.749	0.578	0.264	0.125
Owns livestock	0.726	0.691	0.660	0.637

hand hoeing is most used by farmers in quartile four. Female headed households and farmers who prepared their land before the rains constituted higher proportions of farmers in quartile four while quartile one was made up of larger proportions of farmers who owned livestock and used chemical fertilizers.

4.4 Sources of Technical and Allocative Efficiency

Results from the regression analysis for technical and allocative efficiency models are shown in Table 6. There were seven dummy variables for tillage methods of which three were conservational (ripping, Zero tillage and planting basins) and the remainder were conventional tillage systems (conventional hand hoeing, ploughing, ridging and bunding). In the regression, conventional hand hoeing was used as the reference dummy. The anticipated signs on conservational tillage methods were positive. However, results obtained from the study were mixed in that both conservational and conventional tillage methods are observed to significantly affect technical efficiency in either direction. On one hand, farmers who used ripping, a conservational method, were observed to significantly increase their technical efficiency scores and so are farmers who used ploughing, a conventional tillage method. Ripping and ploughing increases technical efficiency by 18 percent and 5 percent respectively beyond scores obtained with conventional hand hoeing and the relationships were significant at 95 percent and 99 percent confidence level respectively. Allocatively, ripping was observed to have a tendency to reduce while ploughing exhibited a tendency to increase efficiency. Nonetheless, what is common between the two diverse significant methods is that they are all mechanized tillage methods. Farmers who use mechanized equipment are likely to be more efficient than those who use conventional hand hoeing. Such farmers are more likely to prepare and plant maize on time hence improving their yields and at the same time reducing their labour requirements in land preparation, planting and weeding. This could partly explain why Southern Province has the largest proportion of efficient farmers both technically and allocatively compared to other provinces. Farmers in southern have greater access to draught power and are usually more likely to use ripping and ploughing as opposed to conventional hand hoeing. Bunding was another tillage method significantly affecting technical and allocative efficiency. Using bunding for land preparation made a farmer six percent and two percent less efficient technically and allocatively respectively compared to one using conventional hand hoeing. The rest of the tillage methods were insignificant.

Table 5: Determinants of Technical and Allocative Efficiency

Variables	Technical Efficiency	Allocative Efficiency
Tillage methods(1=yes, 0=no)		
Ploughing(1= yes, 0=no)	0.0515***	0.0045
	(0.013)	(0.004)
Planting basins(1= yes, 0=no)	0.0238	0.0034
	(0.032)	(0.008)
Zero tillage(1= yes, 0=no)	-0.0163	-0.0027
	(0.020)	(0.006)
Ripping(1= yes, 0=no)	0.1806**	-0.0014
	(0.089)	(0.019)
ridging(1= yes, 0=no)	0.0082	-0.0024
	(0.013)	(0.003)
Bunding(1= yes, 0=no)	-0.0631*	-0.0243**
	(0.036)	(0.010)
Tillage before rains(1=yes, 0=no)	0.0161	0.0012
	(0.010)	(0.003)
Manure dummy(1=yes, 0=no)	0.0007	-0.0047
	(0.020)	(0.005)
Seed type dummy (1=yes, 0=no)		
OPV seed	0.0093	-0.0015
	(0.059)	(0.021)
Certified Hybrid Seed	0.0736***	0.0099***
	(0.012)	(0.003)
Gender (1=yes, 0=no)	0.0123	0.0024
	(0.010)	(0.003)
Log household size	-0.5424***	-0.0390***
	(0.010)	(0.005)
Livestock ownership (1=yes, 0=no)	0.0195**	0.0069**
	(0.010)	(0.003)
Extension Dummy	0.0319	0.0102
	(0.023)	(0.006)
Log farm size	-0.0546***	-0.0160***
	(0.007)	(0.003)
Log farm size squared	0.1342***	0.0328***
	(0.005)	(0.003)
Active in agric activities(1=yes, 0= no)	0.0221**	-0.0011
	(0.011)	(0.003)
Years of schooling	0.0071***	0.0009**
	(0.001)	(0.000)
Fertilizer dummy(1= yes. 0=no)	0.1307***	-0.0708***
	(0.011)	(0.003)
Rainfall	0.0003	0.0001
	(0.000)	(0.000)

Age of household head (1=yes, 0=no)		
0 t0 25 years	-0.0206	-0.0106*
	(0.015)	(0.006)
56 years and older	-0.0119	0.0015
	(0.011)	(0.003)
Constant	-0.9305***	0.1127***
	(0.179)	(0.041)
Observations	5,165	5,165
R-squared	0.5585	0.3456

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Zero tillage had a tendency to reduce both technical and allocative efficiencies while planting basins show a tendency to increase technical and allocative efficiency. Ridging showed the ability to improve technical efficiency while reducing allocative efficiency.

Comparing farmers who tilled the land after the rains and those who tilled before the rains shows positive coefficients on technical and allocative. Tiling the land before the rains had a tendency to increase both types of efficiency. Farmers who tilled the land before the rains are more likely to plant early and improve their yields. Such farmers are more often than not, likely to have used conservational tillage methods or mechanized tillage services.

Maize is a crop that uses a lot of nitrogen and phosphorus for its growth. Therefore fertilizer use is an important determinant of efficiency. Two dummy variables representing use of fertilizer were created to see the influence of chemical and organic (manure) fertilizers on efficiency. Results show that farmers who use manure have tendencies to improve technical but reduce allocative efficiencies. Despite the tendency for manure to improve technical efficiency very few farmers were seen to be using manure (5.72 per cent). Various reasons would explain this phenomenon despite the vast number of potential advantages from organic fertilizer. In areas where livestock rearing is sparse, manure is not easily accessible. Apart from that, most farmers want to see such quick results as fertilizer gives. Manure takes time before the results can be seen. It also has to be applied in bulk to reach the recommended nutrient levels.

Similarly, farmers who use chemical fertilizers were seen to significantly improve their technical efficiency levels by 13 percent while reducing their allocative efficiency by seven percent compared to those who don’t use fertilizer. Both relationships were significant at 99 percent confidence levels. The technical gains from fertilizer use were not large enough to offset the high cost of fertilizer. This could be partly explained by the wrong fertilizer application rates. Table 1 shows that the average application rate among farmers who used fertilizer was 265 kg/ha (top plus basal dressing) when the generally recommended rate is 400kg/ha.

Farmers have various options before them on what type of seed they use given the constraints facing them. Some farmers used certified hybrid seeds; others used recycled hybrids or local varieties and yet others used open pollinated varieties. In the regression model, the dummy for local and recycled hybrid seed was omitted ,as it was the most used, to see how farmers using hybrid seed and OPVs perform relative to those using local and recycled hybrid seeds. The coefficients on Open Pollinated varieties were positive for technical and negative for allocative efficiency whereas for certified hybrid seed the coefficients were positive and significant for both. Use of certified hybrid varieties significantly increased technical and allocative efficiencies by seven percent and one percent respectively with 99 percent confidence. The cost of certified hybrid seeds is high but its productive capacity is large enough that it offset the high production cost and farmers still remain allocatively efficient. Despite the gains in technical and allocative efficiency, only 34 percent of the farmers used certified hybrid seeds. This is probably because of high prices for hybrid seeds which makes them unaffordable to most subsistence maize producers.

Education attainment of household head is a proxy for human capital. Educated farmers are expected to be more efficient which is true for this study. Education attainment in this study is presented by the number of years spent in formal schools. Increasing the number of years spent in school by one year increases technical efficiency by 0.7 percent while allocative efficiency increases by 0.1 percent and both relationships are significant. These results were similar to those found by Shafiq and Rehman (2000) and

Chirwa (2007) who found a positive relationship between higher number of years spent in school and high level efficiency. This could be because more educated farmers may have better access to extension services, financial institutions and market information. Furthermore, such farmers respond fast to new technologies and appreciate correct management practices like timely planting and weeding, the correct amount of fertilizer to be applied, correct seed rate and general management of the farm.

The majority of households were male headed and these were included in the regression to see how they perform compared to their female counterparts. The regression produced a positive coefficient in both regression models indicating the tendency for male headed households to have higher efficiency scores. This could probably be explained by the fact that the male-headed households are likely to be wealthier and can acquire more productive and expensive technologies faster.

Farmers were classified into three age groups. The first group consisted of farmers aged between zero and 25 years. The next group was made up of ages between 26 and 55 while the last group consisted of farmers older than 55 years. The second group was the reference dummy as it had the largest population. The results indicated that the first group had lower efficiency scores compared to the second group in both regression models. Farmers who were less than 25 years of age exhibited a tendency to have lower technical efficiency scores while having significantly lower allocative efficiency scores. In a similar manner, farmers older than 55 years exhibit a tendency to have lower technical efficiency scores except they also exhibit tendencies for higher lower allocative efficiency scores than farmers in group two. Older farmers are more likely to be less efficient because their physical strength starts declining and they become less responsive to new technologies compared to younger energetic farmers. According to Hussain (1989), older farmers are less likely to have contacts with extension agents and are less willing to adopt new practices and modern inputs. On the other hand, young farmers are usually inexperienced and only became skillful as they grow older. Farmers between 26 and 55 are in their prime age. Such farmers have considerable agricultural experience that enables them to better apply new technologies (Wozniak 1987).

Furthermore, they are likely to have some formal education, and therefore might be more successful in gathering information and understanding new practices, which in turn improves their technical and allocative efficiency.

Household size is another variable that is statistically significant with a negative coefficient. Efficiency reduces as the family size increases. Increasing the size of the family by ten percent reduced technical efficiency by 5 percent and allocative efficiency by 0.3 percent. This result suggests that larger households might utilize family labor beyond the point where the marginal value product of labor is equal to the wage rate. Another probable reason could be that large families are likely to be more financially constrained and hence unable to spare resources for the purchase of fertilizer and certified seed. Similar results were found Bravo-Ureta and Pinheiro (1997) who found a negative and significant correlation between household size and technical and allocative efficiency. However, other studies such as Dolisca and Jolly (2010), found a positive relationship between large family size and efficiency. Their argument is that large household size enhances the availability of labour which may guarantee increased efficiency.

Farmers who owned livestock were expected to be more efficient as they are expected to be less financially constrained. Such farmers are assumed to be better able to raise funds for the purchase of inputs especially fertilizer which is more costly. A dummy was created to represent farmers who own livestock. Farmers who own any kind of livestock were included in the regression. Results show positive and significant coefficients on technical and allocative efficiency. Livestock ownership increased both types of efficiency among farmers. This relationship was statistically significant at 95 percent confidence level. Farmers who owned livestock were two percent and 0.7 percent more technically and allocatively efficient than those who did not own livestock.

Farm size was also included as an explanatory variable in this study. Several studies have looked at the relationship between farm size and efficiency. Mixed results have been reported where some have shown a negative relationship while others have shown a positive relationship. This study added a quadratic term to capture non linearity observed in a prior graphical analysis of technical and allocative efficiency by farm size. Both models show a negative relationship between farm size and efficiency. Increasing the size of the field by ten percent reduces the level of technical efficiency by 0.5 percent and allocative efficiency by 0.1 percent. Efficiency first drops and then starts increasing as the farm size increases. Technical efficiency drops as farm size increase until an optimal farm size of 1.4 ha and starts rising thereafter. Larger farms beyond 1.5 hectares are likely to be more efficient both technically and allocatively than smaller ones. These results are consistent with findings by Helfand and Levine (2000) who observed a non linear relationship between farm size and inefficiency with inefficiency first increasing and then reducing for far larger farms. This could be because farmers who own large farms are more likely to access productive technologies which make them more efficient.

Farmers who were active in agricultural activities were more technically efficient than those who were inactive. They were two percent more efficient compared to their counterparts who were inactive. The coefficient was significant at 95 percent confidence level. Agricultural activities included attending field days, attending agricultural meeting organized by extension agencies in the area. Such farmers have easier access to extension services than those who do not participate in any group activities.

Access to extension services was included as an explanatory variable. Farmers who had access to extension services either in form of literature or contact are expected to exhibit improved efficiency. The results show positive coefficients on both technical and allocative efficiency for farmers accessing extension which are not significant. There was no significant difference in technical and allocative efficiency levels between farmers who received extension services and those who did not. However, the signs on the coefficient indicate tendencies for those who access extension services to have higher efficiency scores than those who did not.

So far most of the analysis on technical and allocative efficiency has been narrowed down to provincial level. However, for the purpose of controlling for spatial differences, the analysis was brought down further to district level. This is because of the possibility of experiencing spatial differences even among districts in the same province. Therefore, dummy variables for the 72 districts of Zambia were created and included in the regression even though they do not appear on the regression output. In the allocative efficiency model, Kitwe which had the lowest mean allocative efficiency was omitted from the regression. Rainfall data captured at district level was included to control for environmental factor like weather elements. The district rainfall amounts do not significantly affect the technical or allocative efficiency scores. However the signs on the coefficient suggest a tendency for higher rainfall areas to have higher efficiency levels.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter begins with the study conclusions highlighting the study objectives and key findings. Based on the key findings, policy recommendations are then highlighted. The chapter concludes with areas of focus for future research.

5.2 Conclusion

The primary objective of this study was to estimate the technical and allocative efficiency of smallholder maize farmers in Zambia and to link the results to farmer and farm characteristics. According to the results from the DEA, technical and allocative efficiency levels among smallholder maize farmers are low. Technical efficiency scores range from 0.071 through 1 while allocative efficiency ranges between 0.001 and 1. Average technical efficiency stands at 30 percent with only 1.18 percent of the farmers being fully efficient and allocative efficiency stands at 12 percent with only 0.33 percent of the farmers being fully efficient. This suggests that there is room for further increase in output without increasing the level and cost of inputs. Output can be increased by 70 percent without altering the level of input usage. Cost can also be reduced by 88 percent without changing the current level of production.

Regression results showed that mechanized tillage methods (ploughing and ripping) improve technical efficiency among farmers. Such tillage methods reduce the amount of labour spend land preparation, planting and weeding and at the same time gives farmers an opportunity to plant early and get the benefits of early planting in form of higher yields. Farmers who are more educated, use certified hybrid seed and own livestock are found to be both technically and allocatively more efficient. Such farmers are wealthier and likely to adopt new technologies and get higher yields which improve their efficiency. Lastly, farmers who are involvement in agricultural activities and use chemical fertilizers are more technically efficiency. They are likely to have better access to extension services and get more yields from use of fertilizers.

5.3 Policy Recommendations

Despite continued government investment in the agriculture sector through Agricultural input subsides, extension services and promotion of new technology, small scale maize farming has remained technically and allocatively inefficient. Three main policy issues emerge from the results of this study. Firstly, in view of the low percentage of farmers using hybrid seed and fertilizers while at the same time using inappropriate seed and fertilizer application rates there is need to devise strategies on how best extension services can be provided to farmers to help appreciate the use of and the importance of adhering to recommended applications. This will help reduce the amount of inputs being used for current output and also increases the yield front hr current level of inputs being used.

Secondly, the results showed that farmers who were involved in community agricultural activities were significantly more efficient than those who were inactive. To this effect there is need to revive community farmers groups within the agricultural camps. This will help farmers acquire and share extension and market information easily. When farmers are better organized it becomes easier even for extension staff to offer extension services to the farmers. In this study only 6 per cent of farmers received extension services. Therefore, there is need to improve the scope of extension work if more farmers are to be more efficient.

Lastly, farmers who owned livestock were technically and allocatively efficiency. There is, therefore, need to promote diversification into livestock production to improve technical and allocative efficiency. Livestock ownership especially oxen acts as a social buffer in times of economic shocks and allows farmers to access expensive but efficiency promoting technologies like certified seed and chemical fertilizers while encouraging use of affordable mechanized tillage through draught power to reduce on time and labor spend on maize production.

5.4 Future Research

Considering that low productivity is a serious national issue for Zambia, it is important that research on productivity and efficiency of maize production continues. There is need for a follow up study. Such a study should include all the relevant variables important in explaining allocative and technical efficiency. Variables to be considered include among others; access to credit, land tenure, access to market information and source of power.

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