TECHNICAL AND ALLOCATIVE EFFICIENCY OF SMALLHOLDER MAIZE FARMERS IN ZAMBIA

By

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A thesis submitted to the University of Zambia in partial fulfillment of the requirements of the degree of Master of Science in Agricultural Economics

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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. It further links the observed efficiency or inefficiency to farmers' socio-economic characteristics through regression analysis.

The results indicate very low levels of technical and allocative efficiency among smallholder maize farmers. Technical efficiency scores range from 0.0005 through 1 while allocative efficiency ranges between .0005 and 1. Average technical efficiency stands at 15 percent with only 0.23 percent of the farmers being efficient and allocative efficiency stands at 12 percent with only 0.27 percent of the farmers being efficient. This means that on average, the level of inputs can be reduced by 85 percent while costs can be reduced by 88percent without reducing output.

The results also show very low utilization of chemical fertilizers despite its positive influence on technical efficiency. Less than half (42%) of the farmers captured in the survey used chemical fertilizer while 6 per cent used organic fertilizers and 7 percent used both chemical and organic fertilizers. Use of hybrid seed, farm size and household size, access to extension services and education attainment of household head are significant determinants of economic efficiency. Involvement in community agricultural activities, use of organic or chemical fertilizers and livestock ownership significantly reduces technical inefficiency among farmers.

Based on these findings, policy makers in agriculture should focus on promoting the use of certified hybrid varieties and chemical fertilizers and diversification of farming enterprises to include livestock. Farmers groups should be encouraged and strengthened to improve access to market information and other extension services. There is also need to improve the scale of extension work. Education facilities should be increased for long term results and farmer education should be emphasized for the short term.

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CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture is the economic engine of most economies in Sub-Saharan Africa (SSA) contributing at least 70 percent of employment, 40 percent of export earnings, and 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 Maize Production in Zambia

Maize (*Zea mays L*.) originated from Latin America and its cultivation is considered to have begun by 3000 BC at the latest. It was introduced to West and East Africa in the 16th century and in Zambia it 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 2. 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.

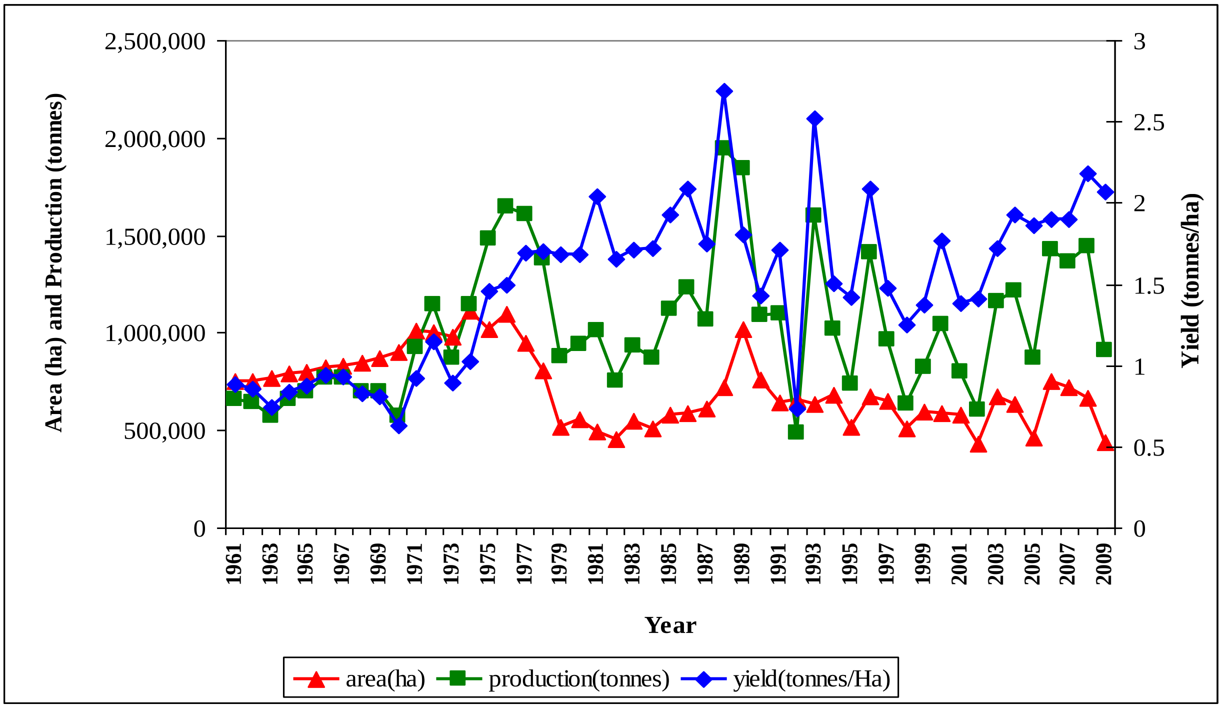

Figure 1: Annual Yield, Planting Area and Production Volumes
Source: Compiled by author from Faostat

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 Problem Statement

The role of 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 1993). Technically efficient farmers are highly productive because they are able to use a minimum level of inputs to produce a given level of output or produce maximum output from a given level of inputs. Similarly, allocatively efficient farmers tend to run more profitable farming enterprises as they are able to produce a given level of output from minimum costs.

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. 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, very few 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 maize technical and allocative efficiency. 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 inefficiencies 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 be also 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 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.

2.3 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)

2.4 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.

2.5 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 1. 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.

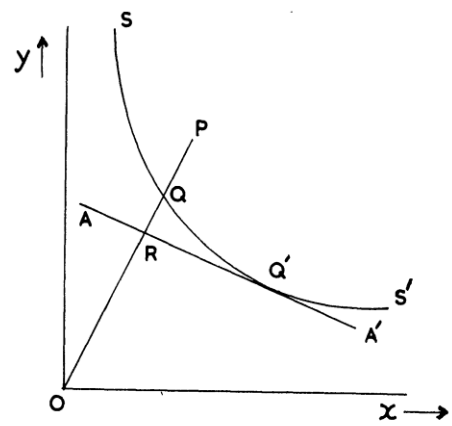

Figure 2: Technical and Allocative efficiency
Source: Ajibefun (2008)

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 (BBC) 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.

2.6 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.

2.7 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.

2.8 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. This study will add on to literature on economic efficiency of maize.

CHAPTER 3

METHODOLGY

3.1 Introduction

This chapter starts with detailed presentation of the data and sampling procedures. It then briefly discuses DEA and the mathematical programming model used to estimate the efficiency scores. The regression model used to identify factors influencing efficiency is described

3.2 Data 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 more 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. The 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).

3.3 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.

3.3.1 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 BBC 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:

$$\min \sum_{h=1}^{z} TE^h \qquad (1)$$

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

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

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

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

$$TE^h \geq 0$$

Source: Fletschner and Zepeda (2002)

Where there are m outputs and n variable inputs, y_s^h is the s^th^ output of unit h, and x_g^h is the g^th^ 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.

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

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

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

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

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

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:.

$$AE^h = \frac{w^h x^h}{w^h x^*} \qquad (3)$$

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.

3.3.2 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 14 (0.26 percent) of the 5,169 observations were fully efficient and hence censored both for technical and allocative efficiency. Because of the negligible level of censoring ordinarily least squares (OLS) was used

$$y_i = x_i \beta + u_i \qquad (4)$$

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, 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 expected 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 composition is another important variable in efficiency. The dependency ratio is used as a proxy for household composition. In this study the dependency ratio is calculated as the ratio between active members in the family to inactive members in a household. The relationship between efficiency and household composition is expected to be negative or positive. Households with relatively fewer active 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 expect 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 expected 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 expected 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.

3.3.3 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) were used to check for linearity. Plots were done for the two continuous variables in the data set, farm size and dependency ratio. The results did not indicate a clear departure from linearity in both models.

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 that the highest VIF was 8.9 belonging to a district dummy, Chipata, while the mean VIF value was 2.8. Since all the VIF values are less than 10 there is no indication of any trouble of multicollinearity.

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 indicated the residuals were normal pattern

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 characteristic 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 13 percent of the farmers have never been to school. Eighty-two percent of the households were headed by males. Farmers' age ranges between 19 and 90 years. The average age is 45 years, with 56 per cent of the farmers being less than 45 years old. These farming households have an average household size of 7. Most of the farming households actually have 5 to 7 members with only a quarter of the respondents having small families with 1 to 4 members.

Conventional hand hoeing is the most frequently used tillage method at 35 percent followed by ploughing at 36 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 (65%) and 36 percent of the farmers used certified hybrid seed. Average seed rate was 35kgs per hectare while average rate of fertilizer is 265kgs per hectare. Amount of fertilizer included both basal and top dressing fertilizer.

Table 1: Farm and Farmers Characteristics

Variable	Units	Mean	Std. Dev.	Min	Max
Fertilizer used	kg/ha	265.2	198.4	0.67	3200
Yield harvested	kg/ha	2429.8	1601.7	6.6	12978
Seed used	kg/ha	34.96	88.7	0.00	274
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
Dependency Ratio		0.51	0.21	0.00	1.00
Owns livestock	1=yes, 0=no	0.68	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 50 years	1=yes, 0=no	0.62	0.49	0.00	1.00
51 and older years	1=yes, 0=no	0.33	0.47	0.00	1.00
Dummies for Education					
Primary	1=yes, 0=no	0.04	0.19	0.00	1.00
Secondary	1=yes, 0=no	0.00	0.07	0.00	1.00
College	1=yes, 0=no	0.14	0.34	0.00	1.00
University	1=yes, 0=no	0.35	0.48	0.00	1.00
None	1=yes, 0=no	0.03	0.16	0.00	1.00
Dummies for Tillage methods					
Conventional hand hoeing	1=yes, 0=no	0.35	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	0.36	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	0.02	0.12	0.00	1.00

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 13 farmers are technically fully efficient and 15 were allocatively fully efficient relative to all other farmers. These farmers use and spend far less to produce a unit of output compared to their counterparts who have been deemed inefficient. The national mean technical and allocative efficiency scores were 15 percent and 12 percent respectively (Table 2). 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 85 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	**Mea n**	**Max**	**Min**	**% of Efficient Farmers**	**Mean**	**Max**	**Min**	**% of Efficient Farmers**
Central	0.18	1.00	0.01	0.05	0.12	1.00	0.00	0.05
Copper belt	0.16	1.00	0.01	0.04	0.10	1.00	0.01	0.04
Eastern	0.15	1.00	0.00	0.04	0.11	1.00	0.00	0.02
Luapula	0.13	0.79	0.00	0.00	0.16	1.00	0.01	0.00
Lusaka	0.15	1.00	0.00	0.02	0.10	1.00	0.01	0.04
Northern	0.15	1.00	0.00	0.02	0.12	1.00	0.01	0.05
N/ western	0.11	0.68	0.01	0.00	0.11	0.42	0.00	0.00
Southern	0.16	1.00	0.00	0.07	0.12	1.00	0.00	0.05
Western	0.07	0.80	0.00	0.00	0.13	0.87	0.01	0.00
National	0.15	1.00	0.00	0.23	0.12	1.00	0.00	0.25

Source: Authors Calculations

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, and Western were the only provinces that had neither a technically nor an allocatively efficient farmer. In terms of mean technical efficiency scores, Central Province had the highest score and Western Province had the lowest.

Luapula Province which did not have a single technically efficient farmer was observed to have the highest mean score (0.16) in terms allocative efficiency followed by Western and then Northern Provinces. Copperbelt was seen to have the lowest mean score of 0.10.

Cumulative percentage plots (Figure 3) were made to see the distribution of the efficiency scores in 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, eighty two percent of the farmers were 25 percent or less as efficient as the fully efficiency farmers. Only two percent of the farmers were 75 percent or more as efficient as the fully efficient farmers. Ninety five percent of the farmers were technically half or less as efficient as the fully efficiency farmers. Allocatively, about 92 percent of the farmers were 25 percent or less as efficient and 99 percent of the farmers were half or less as efficient as the most efficient farmers. Only one percent of the farmers were seen to have allocative efficiency greater than 50 percent.

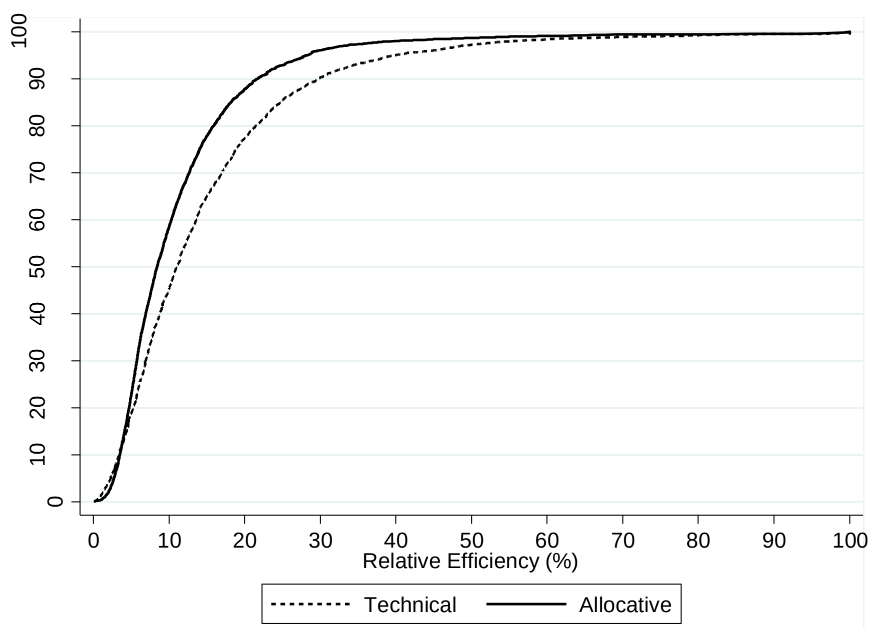

Figure 3: Cumulative Percentage of relative Technical and Allocative efficiency
Source: Compiled by author

Beyond comparing the average efficiency of farmers across provinces, there was an interest to compare the mean efficiencies of these farmers across groups based on their relative efficiency in their provinces. This was done to see how farmers at different levels of efficiency compare across provinces. It is possible for a province to appear more efficient than others because farmers in one group are very efficient and yet farmers in many other groups are very inefficient. In light of this, Technical and Allocative efficiency scores were grouped in quartiles (equal groups of 25) 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. Central Province had the highest mean score in the fourth quartile implying that the last 25 percent of farmers in Central Province were more efficient than the last 25 of farmers in all the other Provinces. Southern Province had a higher provincial mean efficiency than Northern Province. However, looking at the quartiles, Northern Province 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.

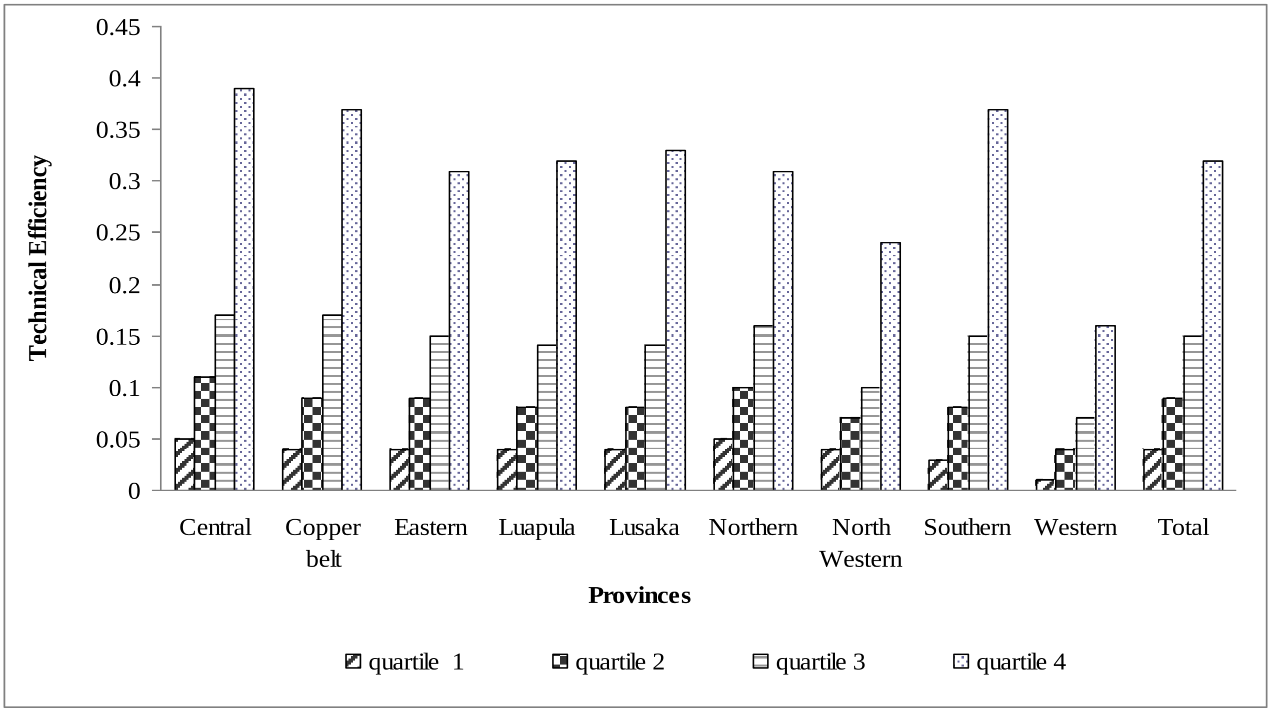

Figure 4: Mean Technical Efficiency across quartiles for each Province
Source: Compiled by author

Allocatively, Luapula Province which did not have a single technically efficient farmer was observed to have the highest allocative mean score in the fourth quarter. The last 25 percent of farmers were relatively more efficient than those of other Provinces. Copper belt and Southern Provinces have 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. Even though Lusaka and Northern Provinces had the same mean allocative scores, Northern Province had the majority of farmers doing better than those of Lusaka. In all the quartiles but for quartile four, Northern Province has higher mean allocative scores.

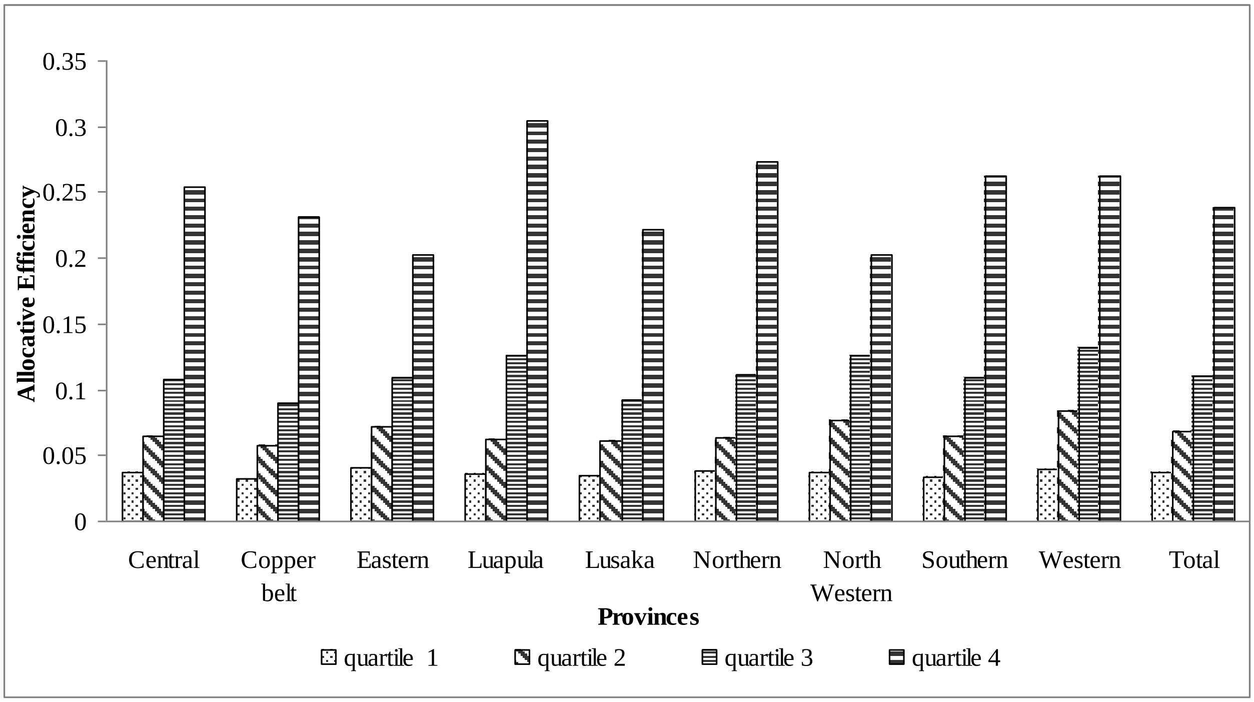

Figure 5: Mean Allocative Efficiency across quartiles for each Province
Source: Compiled by author

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 among the various tillage methods employed by the farmers, the largest proportion of farmers in the fourth quartile ploughed their land where as the largest proportion of farmers in the first quartile used conventional hand hoeing. Majority of farmers in the first quartile used local and recycled hybrid seeds while more than half of those in quartile four used certified hybrid seed. Quartile four consists of more farmers who used chemical fertilizer than those who did not.

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 hand hoeing is most used by farmers in quartile four. Farmers who access extension and were active in agricultural activities constitute higher proportions of farmers in quartile four.

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

	Technical Efficiency quartiles			
Variable	**1**	**2**	**3**	**4**
Dummies for tillage methods				
Conventional hand hoeing	0.401	0.374	0.363	0.258
Planting basins	0.030	0.023	0.026	0.026
Zero tillage	0.047	0.043	0.043	0.022
Ploughing	0.264	0.345	0.354	0.464
Ripping	0.002	0.003	0.003	0.008
Ridging	0.234	0.200	0.199	0.218
Bunding	0.023	0.013	0.012	0.005
Land tillage after the rains	0.668	0.655	0.672	0.703
Land tillage before the rains	0.332	0.345	0.328	0.297
Used manure	0.057	0.051	0.064	0.085
Did not use manure	0.943	0.949	0.936	0.915
Used certified hybrid seed	0.006	0.005	0.009	0.002
Used OPV	0.238	0.306	0.386	0.514
Used local & recycled hybrid seed	0.756	0.689	0.606	0.483
Dummies for Education levels				
Primary	0.587	0.587	0.522	0.483
Secondary	0.208	0.247	0.303	0.350
College	0.018	0.032	0.042	0.057
University	0.003	0.001	0.004	0.012
None	0.184	0.133	0.129	0.098
Dummies for age groups				
0 to 25 years	0.058	0.068	0.056	0.045
26 to 50 years	0.745	0.748	0.766	0.758
51 and older years	0.197	0.184	0.178	0.197
Male household head	0.768	0.821	0.808	0.880
Female household head	0.232	0.179	0.192	0.120
Inactive in agric activities	0.241	0.244	0.299	0.343
Active in agric activities	0.759	0.756	0.701	0.657
Did not Access extension services	0.963	0.953	0.932	0.904
Accessed extension services	0.037	0.047	0.068	0.096
Did not use chemical fertilizer	0.243	0.358	0.495	0.621
Used chemical fertilizer	0.757	0.642	0.505	0.379
Owns livestock	0.597	0.665	0.691	0.763
Did not own livestock	0.403	0.335	0.309	0.237
farm size	0.875	0.960	1.139	2.111

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

	Allocative Efficiency quartiles			
Variable	**1**	**2**	**3**	**4**
Dummies for tillage methods				
Conventional hand hoeing	0.295	0.339	0.374	0.388
Planting basins	0.026	0.025	0.031	0.023
Zero tillage	0.032	0.035	0.042	0.046
Ploughing	0.384	0.358	0.340	0.344
Ripping	0.002	0.003	0.005	0.005
Ridging	0.253	0.228	0.192	0.177
Bunding	0.009	0.012	0.017	0.016
Land tillage after the rains	0.690	0.678	0.654	0.677
Land tillage before the rains	0.310	0.322	0.346	0.323
Used manure	0.063	0.077	0.060	0.058
Did not use manure	0.937	0.923	0.940	0.942
Used OPVs	0.005	0.006	0.007	0.004
Used certified hybrid	0.469	0.405	0.293	0.275
Used local & recycled hybrid seed	0.526	0.588	0.700	0.721
Dummies for Education levels				
Primary	0.512	0.534	0.564	0.570
Secondary	0.316	0.284	0.254	0.256
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 50 years	0.766	0.763	0.759	0.729
51 and older years	0.201	0.184	0.178	0.192
Male household head	0.851	0.833	0.807	0.786
Female household head	0.149	0.167	0.193	0.214
Inactive in agric activities	0.309	0.317	0.277	0.224
Active in agric activities	0.917	0.683	0.723	0.776
Did not Access extension services	0.083	0.057	0.059	0.048
Accessed extension services	0.691	0.943	0.941	0.952
Did not use chemical fertilizer	0.749	0.577	0.735	0.123
Used chemical fertilizer	0.251	0.423	0.265	0.877
Owns livestock	0.726	0.692	0.660	0.637
Did not own livestock	0.274	0.308	0.340	0.363

The absence of efficient farmers could be partly explained by Table 5 which shows the suitability of maize in the nine provinces under high input management. Western Province which had the lowest maximum score appears to be unsuitable for maize production. Out of the 46 Standard Enumeration Areas in the province, 96 per cent are not suitable for maize production both under high and low input management levels. The remaining 4 percent are only moderately suitable. The other two provinces North-Western and Luapula have much of the land being just moderately suitable to unsuitable. On the contrary, Central Province which had the highest mean efficiency score had the highest numbers (73 %) of the SEAs being suitable for maize production.

Table 5: % of SEAs Suitable for Maize Production in each Province

		% of SEAs by Suitability under High Input Management			
Province	Total No. of SEAs	Suitable	Moderately Suitable	Marginally Suitable	Unsuitable
Central	40	72.50	15.00	0.00	12.50
Copper belt	24	8.33	66.67	25.00	0.00
Eastern	72	72.22	0.00	1.39	26.39
Luapula	49	8.16	48.98	6.12	36.73
Lusaka	14	42.86	35.71	0.00	21.43
Northern	80	26.25	36.25	10.00	27.50
North-Western	30	6.67	43.33	16.67	33.33
Southern	50	26.00	24.00	0.00	50.00
Western	46	0.00	4.35	0.00	95.65
Total	405	31.85	26.42	5.68	36.05

Source: Zambia Agricultural Research Institute.

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 negative. However, results obtained from the study were mixed. Farmers who used ripping, a conservational method, were found to significantly increase their efficiency scores by seven percent when compared with those who used conventional hand hoeing and this relation was significant at 95 percent confidence level. Ripping was also observed to have a tendency to improve allocative efficiency. Ploughing, a conventional method was seen to increased technical efficiency but reduce allocative efficiency compared to conventional hand hoeing. Farmers who ploughed their fields, significantly increased technical efficiency by two percent but reduced allocative efficiency by one percent. The relationships were significant at 99 percent and 95 percent confidence levels respectively. However, what is common between these two methods is that they are all mechanized tillage methods. This seems to suggest that farmers who use mechanized equipment are likely to be more efficient. Zero tillage had a tendency to reduce both technical and allocative efficiencies while bunding indicates a propensity to reduce technical efficiency but improve allocative efficiency. Planting basins and ridging have positive coefficients on technical efficiency and negative coefficients on allocative efficiency implying tendencies to improve technical efficiency and reduce allocative efficiency respectively.

Comparing farmers who tilled the land after the rains and those who tilled before the rains gives a negative coefficient on technical efficiency and a positive sign on allocative efficiency. Tiling the land after the rains had a tendency to reduce technical efficiency but significantly increased allocative efficiency. Farmers who tilled the land

Table 6: Determinants of Technical and Allocative Efficiency

	Technical Efficiency		Allocative Efficiency	
Variables	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Tillage methods(1=yes,0=no)				
Planting Basins	0.003 (0.012)	0.30	-0.001 (0.008)	-0.01
Zero Tillage	-0.010 (0.007)	-1.45	-0.004 (0.007)	-1.19
Ploughing	0.020 (0.005)***	4.21	-0.009 (0.005)**	-3.93
Ripping	0.068 (0.032)	1.15	-0.004 (0.017)	-0.58
Ridging	0.005 (0.005)***	2.75	-0.006 (0.004)	-3.70
Bunding	-0.004 (0.004)	-1.72	0.003 (0.014)	2.81
Tillage after rains(1=yes,0=no)	-0.004 (0.004)	-1.12	0.010 (0.003)***	4.13
No Manure (1=yes, 0=no)	- 0.009 (0.008)	-1.09	-0.004 (0.006)	0.80
Seed type (1=yes,0=no)				
OPV	-0.009 (0.020)	-0.43	-0.011 (0.020)	-0.55
recycled Hybrid & Local	-0.030 (0.004)***	-5.87	-0.001 (0.003)***	-3.20
Education (1=yes,0=no)				
Primary	0.004 (0.004)	0.86	0.009 (0.004)**	2.35
Secondary	0.017 (0.005)***	3.26	0.012 (0.004)***	2.95
College	0.019 (0.010)*	1.83	0.006 (0.006)*	1.97
University	0.100 (0.039)**	2.57	0.085 (0.039)**	2.20
Age groups(1=yes, 0=no)				
0 to 25 years	-0.006 (0.006)	-0.91	-0.001 (0.006)	-0.05
51 and older	-0.002 (0.003)	-0.56	-0.001 (0.003)	-0.17
Gender(1=female,0=male)	-0.005 (0.004)	-1.42	0 .015 (0.004)**	3.77
Dependency ratio	-0.039 (0.009)	-4.45	-0.010 (0.010)	-0.99

Table 6 cont.

	Technical Efficiency		Allocative Efficiency	
Variables	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Livestock (1=no,0=yes)	-0.015		0.008	
	(0.003)***	-5.01	(0.003)**	2.28
Inactive (1=yes,0=no)	-0.008		0.009	
	(0.004)**	-2.26	(0.003)***	2.99
Extension (1=no,0=yes)	-0.020		-0.010	
	(0.009)**	-2.07	-0.007	-1.51
Farm size	0.030		0.010	
	(0.002)***	13.90	(0.002)***	4.01
Fertilizer use (1=no,0=yes)	-0.044		0.080	
	(0.004)***	-11.15	(0.003)***	23.93
Constant	0.218		0.090	
	(0.014)***	15.29	(0.011)***	8.23
Observation	5169		5169	
R- squared	0.329		0.198	

***,* significance level at 1%, 5% and 10% consecutively*

after the rains were one percent more allocatively efficient and the correlation was significant at 95percent confidence level.

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 do not use manure have tendencies to reduce both technical and allocative efficiencies. Despite the tendency for manure to improve technical and allocative 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 4 percent compared to those who don't use fertilizer. However, use of chemical fertilizers was seen to reduce allocative efficiency. Farmers who did not use fertilizer increased their allocative efficiency by 8 percent compared to farmers who used fertilizer and the correlation was significant at 99 percent confidence level. This could be because farmers using chemical fertilizer were not applying the recommended rates. Table 1 shows that the average application rate was 262 kg/ha (top plus basal dressing) and the generally recommended rate was 400kg/ha. The technical gains from these rates are not large enough to offset the cost of fertilizer. Use of chemical fertilizer reduces allocative efficiency by four percent and the relationship was significant at 99 percent confidence level.

Farmers have various options before them on what type of seed they use given the constraints before 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 hybrid seed was omitted so as to see how farmers not using hybrid seed perform relative to those using certified hybrid seeds. The coefficients on both Open Pollinated and Recycled hybrid and local varieties were negative indicating a tendency to reduce technical and allocative efficiency. Farmers who use recycled hybrid and local varieties significantly reduced technical efficiency by three per cent and allocative efficiency by one percent when compared to those who used certified hybrid seeds. Both relationships were significant at 99 per cent confidence levels. 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. Use of open pollinated varieties also had negative coefficients indicating its inclination towards reducing technical and allocative efficiency among farmers as compared to use of certified hybrid seed. 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 was classified into five dummies: no education, primary, secondary, college and university. Dummy for no education was used as the reference variable. Results show that there was no significant difference in technical efficiency between farmers who had never been in school and those who had been in school up to primary level. Nevertheless, those who had been in primary school were allocatively more efficient. Such farmers were one percent more allocatively efficient with the relationship being significant at 95 percent confidence level. Farmers who had been in school up to secondary level were observed to be technically and allocatively efficient more efficient by two percent compared to those who had not been in school. These relationships were significant at 99 and 95 percent confidence levels for technical and allocative efficiency respectively. Farmers who had gone as far as college level in their education were also seen to have higher technical and allocative efficiency levels. Technical and allocative efficiency increased by two and one percent respectively compared to unschooled farmers. The correlations were significant at 90 percent confidence level. The most educated farmers were seen to be the most efficient. Farmers who were university graduates were able to increase technical efficient by 12 percent and allocative efficiency by nine percent compared to those who have not attained any schooling. The relationships were significant at 95and 99 percent confidence levels respectively. From these results we see that education of the household head increases the technical and allocative efficiency of farmers. 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. Female household heads were included in the regression to see how they perform compared to their male counterparts. The regression produced a negative coefficient indicating the tendency for female headed households to have lower 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. Whereas Male household heads were technically more efficient compared to female household heads, female household heads were found to be more allocatively efficient. The relationship was significant at 99 percent confidence level. Female headed farmers were more efficient than male headed households by 2 percent. This could be because women are more aware or concerned with the food requirements of the family (Thomas 1990).They may therefore be more likely than men to recognize the advantages of cost saving technologies and are hence able to produce at lower costs. In addition female household heads are normally members of farmer groups and are more likely to regularly attend meetings organized by extension workers. This makes them more knowledgeable and certain to adopt new technologies.

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 59 while the last group consisted of farmers older than 59 years. The second group was the reference dummy. The results indicated that the first and last groups both had lower efficiency scores compared to the second group. Farmers who were less than 25 years of age and more than 59 years of age both have a negative coefficient for both types of efficiency implying a tendency to reduce efficiency compared to those aged between 26 and 59. 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 59 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.

Dependency ratio which was calculated as the ratio of the number of inactive members in the family (which consisted of children below the age of 15 and adults above the age of 59 years) to the total household size is another variable that was statistically significant at 99 percent confidence level for technical efficiency. Technical efficiency was observed to decrease by 4 percent as the dependency ratio increased by one percent. Efficiency reduces as the dependency ratio increases. Farmers with a larger proportion of inactive members are likely face labour constraints. Such farmers may not be able to prepare the land and plant seeds on time hence losing out on yields. Furthermore, families with more dependants are likely to be more financially constrained and hence unable to spare resources for the purchase of fertilizer and certified hybrid seed. Despite being an important factor in technical efficiency, dependency ratio does not affect allocative efficiency. However, it had a negative coefficient indicating a tendency to reduce efficiency among farmers.

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 do not own any form of livestock were included in the regression. Results show a negative coefficient on technical efficiency and a positive coefficient on allocative efficiency. Livestock ownership increased technical efficiency among farmers. This relationship was statistically significant at 99 percent confidence level. Farmers who own livestock were one percent more technically efficient. On the other hand farmers who did not own livestock were more allocatively efficient than their counterparts who owned 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 shows a positive relationship between farm size and efficiency. Increasing the size of the field by one hectare increased the level of technical efficiency by 3 percent and allocative efficiency by one percent. Farmers who had larger fields were seen to be more efficient both technically and allocatively. The relationships were significant at 99 percent confidence levels. This results are consistent with findings by Kaiser (1988) and Sharma et al. (1 999)

Farmers who were active in agricultural activities were more technically efficient than those who were inactive. They were one 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 a negative coefficient on both technical and allocative efficiency for farmers not accessing extension. Farmers who received extension service were seen to be 2 percent more efficient than their counterparts who did not access any extension service and the correlation was significant at 95 percent confidence level. Unfortunately only 5 percent of the respondents reported as being visited by extension staff or received literature on agricultural practices. There was no significant difference in allocative efficiency levels between farmers who received extension services and those who did not. However, the coefficient was negative for farmers not accessing extension services indicating a tendency for those who access extension services to have higher efficiency score 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. In the technical efficiency model Kalabo, a district in Western provinces and one that had the lowest mean efficiency in the country was used as the reference variable. The results showed that Kalulushi from Copperbelt Province, Kazungula in Southern Province and Sesheke and Senanga from Western Province had negative coefficients indicating the tendency to have lower efficiency scores compared to Kalabo district. The rest of the districts had positive coefficients which were significant at 95 percent confidence level except for Shangombo, Lukulu and Mongu in Western Province, Sinazongwe, Gwembe, Livingstone and Mazabuka in Southern Province, Kafue in Lusaka Province and Mwense in Luapula Province. In the allocative efficiency model, Kitwe which had the lowest mean allocative efficiency was omitted from the regression. Results show that Kalulushi, Chadiza, Katete Luangwa, Kasempa, Solwezi, Ithezi-Ithezi, Kazungula, Sinazongwe, Senanga, Shangombo and Sesheke showed tendencies to have lower efficiency scores compared to Kitwe. The rest of the districts were either significantly positively correlated with allocative efficiency or had tendencies to improve efficiency.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter begins with the study conclusions where the study objectives and key findings are summarized. 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 0.0005 through 1 while allocative efficiency ranges between .0005 and 1. Average technical efficiency stands at 15 percent with only 0.23 percent of the farmers being efficient and allocative efficiency stands at 12 percent with only 0.27 percent of the farmers being 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 85 percent without altering the level of input usage. Cost can also be reduced by 88 percent without changing the level of production.

Central Province has the highest level of relative efficiency among farmers and also the largest proportion of fully efficient farmers. The situation in Western is opposite, Western province has the most inefficient farmers with none of them being fully efficient. This is partly explained by the different suitability levels of the two Provinces for maize production. Central Province is more suitable for maize production than Western Province. It is therefore important that other cash crops be considered in provinces like Western Province where the soils and weather conditions are marginally suitable for maize production.

Results showed that mechanized tillage methods (ploughing and ridging) improve technical efficiency among farmers. Use of fertilizers and certified Hybrid seed improves both technical and allocative efficiency. Involvement in agricultural activities and education of household head are other significant determinants of technical efficiency. Such farm and farmer characteristic should be encouraged to enhance efficiency among small holder farmers.

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. Four main policy issues emerge from the results of this study. Firstly, in view of the low percentage of farmers using hybrid seed, there is a need to promote adoption of hybrid seeds among smallholder maize farmers to increase unit yields. Results show that use of hybrid seed significantly improves technical and allocative efficiency among farmers. Therefore, advocating for increased adoption of hybrid seed is one sure way targeting inefficiency among the farmers.

Secondly, the study observed that only 42 percent of the farmers acquired and used fertilizer and yet the results show that use of fertilizer improves technical efficiency among farmers. If more farmers can access the fertilizer, efficiency among farmers would improve significantly. There is therefore need to devise ways of making fertilizer more accessible to small scale farmers.

Thirdly the results showed that farmers who were involved in community agricultural activities were significantly less inefficient 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 5 per cent of farmers received extension services and the performance of this group was better than the rest. 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 efficiency. There is therefore need to promote diversification into livestock production to improve technical efficiency.

5.4 Future Research

Considering that low productivity is a serious national issue for Zambia, it is important the 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, source of power.

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