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ANALYSIS OF ECONOMIC EFFICIENCY OF CUMIN (CUMINUM CYMINUM) IN NORTH ACHEFER DISTRICT, AMHARA NATIONAL REGIONAL STATE, ETHIOPIA

BY

TAREKEGN NEWUT TAKELE

JUNE, 2017

ADDIS ABABA, ETHIOPIA

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A THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES, ST. MARY'S UNIVERSITY, INSTITUTE OF THE AGRICULTURE AND DEVELOPMENT STUDIES, FOR PARTIAL FULLFILLMENT OF THE REQUIREMENTS FOR THE MASTERS OF SCIENCE DEGREE IN AGRICULTURAL ECONOMICS

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As members of the Examining Board of the final MSc. open defence, we certify that we read and evaluated the thesis prepared by TarekegnNewut and recommend that it be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Agricultural Economics.

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DECLARATION

I declare that this Msc. thesis is my original work, and has never been presented for the award of any degree in this or any other university and all source of materials used for the thesis have been duly acknowledged.

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June, 2017

ENDORSEMENT

This thesis has been submitted to St. Mary's University, School Of Graduate Studies for examination with my approval as a university advisory.

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LIST OF ACRONYMS

AE	Allocative Efficiency
ANRS	Amhara National Regional State
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
EE	Economic Efficiency
LR	Likelihood Ratio
ML	Maximum Likelihood
NAWARDO	North AcheferWoreda Agriculture and Rural Development Office
NGOs	Non-Governmental Organizations
SFPF	Stochastic Frontier Production Function
TE	Technical Efficiency
TLU	Tropical Livestock Unit

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ABSTRACT

This study aimed at determining the level of technical, allocative and economic efficiencies of cumin producer farmers in north Achefer district. It also identified the factors affecting the efficiency of producers in the study area. Data were generated by adopting a cross-sectional survey design during the 2016/17 production year from 122 randomly selected cumin producing farm households. Data were analyzed using the Stochastic Frontier Production Function (SFPF) to estimate the level of technical, allocative and economic efficiencies of the producers. Further, the Tobit model was used to identify the factors affecting the efficiencies cumin producers. The results indicated that the level of technical, allocative and economic efficiency of cumin producers were 89%, 43% and 38%, respectively. The mean of technical and allocative efficiencies imply that there is a possibility of increasing productivity by 11% without using extra inputs and by 57% without increasing the cost of production, respectively. The Tobit model results revealed that age, slope of plots, and perception of farmers on agricultural policy had a significant positive effect, and sex of household head had negative significant effect on technical efficiency. Education, frequency of extension visit, perception on agricultural policy and livestock holding had positive significant effect on allocative efficiency of cumin producers, while age of household head, credit utilized and perception on agricultural policy were found to have positive significant effect on economic efficiency of the producers. The results showed that there is an opportunity to increase the efficiency of cumin producers in the study area. Therefore, the policies and strategies in development and research may act on these variables to increase the efficiency level of cumin producing farmers.

Keywords: Cumin, Efficiency, Cobb-Douglas, Stochastic Frontier and Tobit, North Achefer District

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Efficiency is the most widely used concept in economics. It is measured by comparing the observed output against the feasibleoutput. The scarcity of resources is the major factor that makes the improvement in efficiencyso important to an economic agent or to a society. Efficiency is the ratio of the value of output produced to the cost of input used (Jema,2008).

According to Koopmans (1957) 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. AE is attained when the farmer adjusts outputs and inputs levels to reflect relative prices and the production technology. Technical and allocative efficiency are then combined to give economic efficiency, which is sometimes referred to as overall efficiency (Farell, 1957; Coelli*et al.*, 1998).

Several authors have investigated the relationship between efficiency and various socioeconomic variables using two alternative approaches (for a review of several of these papers, see Ray,1988, Kalirajan, 1991, Bravo-Ureta and Rieger, 1994, Kifle,2014). One approach is to compute correlation coefficients to conduct other simple nonparametric analyses. The second way, usually referred to as a two-step procedure, is to first measure farm level efficiency and then to estimate a regression model where efficiency is expressed as a function of socioeconomic attributes.

Analysis of the effects of firm-specific factors on economic efficiency has generated considerable debate in frontier studies. The economic efficiency estimates obtained are regressed on some socioeconomic factors using the Tobit model. This use of a second stage regression model of determining the socioeconomic attributes in explaining inefficiency has been suggested in a number of studies (Nartea, 2004).

Battese and Coelli(1995) present the main empirical reference regarding the determinants of TE in agriculture. The central conjecture these authors postulate is the joint estimation of a model that includes both the efficient frontier of agricultural production and the variables that influence the inefficiency of production. This makes the study to be problem oriented and important to stakeholders working in the study area. Developing countries can benefit much from efficiency studies that show the possibility of increasing productivity by improving efficiency without increasing the resource base or developing new technologies (Tewodros, 2001).

Cumin (CuminumCyminum) is a flowering plant in the family Apiaceae, native from the east Mediterranean countries to South Asia. In the world, around 300,000 tons of cumin is produced per year. In 2007, India produced around 175,000 tons of cumin on an area of about 410,000 hectare which means the average yield was 0.43 tons per hectare (Sastry and Ananndraj, 2013).India is the main producer and consumer country in the world. It produces 70%, and consumes63% of the world supply, and countries like Syria (7%), Iran (6%), and Turkey (6%) combined produce 19%. The remaining 11% comes from other countries.

Cumin is the second Ethiopian cash crop exported next to ginger (Spice Sector Strategy Coordinating Committee, 2010). In Ethiopia, the three main cumin producing regional states are South Nation Nationalities and People of Ethiopia, Amhara and Oromiaregional states (MOA, 2016). Ministry of Agriculture (2016) reported that cumin nationally covered 1000 hectares of land in 2016, and about 3000 kilo gram was harvested. Cumin is the dominant cash crop in North AcheferWoereda. According to North AcheferWoreda (2010),the total area coverage by cumin was greater than 600hectares, and the total annual production of the cumin was above1800 kg.But, the production and land coverage by cumin is decreasingover time, unless it is compensated by improving the productivity of the crop per unit area. Among the challenges that cumin producers are facing, lack of improved seed, recommended fertilizer rate, poor knowledge on post-harvest handling,and absence of improved agriculture practices could be mentioned.

1.2. Statement of the Problem

The growing gap between spice demand and supply in Ethiopia is mainly attributed to the very low productivity of the agricultural sector. The serious reliance on obsolete farming techniques, poor complementary services such as extension, credit, marketing, infrastructure and poor and biased and agricultural policies are among the major factors that have greatly constrained the development of Ethiopia's agriculture (MOA, 2013). Farmers in the study area practice mixed farming system. Among the spice grown in the study area, cumin is the major crop in terms of volume of the production and area cultivated. It is also the major source of cash income to the farmers among the crops grown in the area (NAWRDO,2012). Accelerating the adoption of improved technologies by small-scale farmers is believed to result in higher output. However, the promoted technologies have not been used to full potential and no substantial gains could be achieved by using the technologies alone. Production inefficiency of smallholder farmers in Ethiopia has been one of the key factors limiting agricultural productivity especially that of spicy crops including cumin (MOA, 2016).

Therefore, in order to improve cumin production and productivity, it becomes vital to undertake economic efficiency analysis at farm level under the existing technology to enhance the contribution of the cumin sector to national economy. Moreover, identifying the extent of efficiency and the factors that contribute to it is of a paramount importance on the level of resource use efficiency in cumin production. Such information is useful for formulating appropriate policies and for reducing the level of economic inefficiency.

Many people, in different sectors, have done efficiency studies in Ethiopia. However, much of these studies concentrated on the analysis oftechnical efficiency (Tewodros, 2001; Temesgenand Ayalneh, 2005; Kinde, 2005; Fekadu, and Bezabih, 2009, and Berket, 2015). Examination of thetechnical efficiency alone understates the benefits that could be derived by producers from improvements in overall performance.There are also few empirical studies in Ethiopia which have done economic efficiency analysis for different crops (Jema, 2008; Nejuma, 2012; Solomon, 2012; and Kifle, 2014). These major studies focused on major food crops like Maize and Wheat and also on vegetables. However, there is no study done on theeconomic efficiency of cumin producers in Ethiopia in general and in the study area inparticular. Hence, there is a need to fill the existing knowledge gap by addressing issues related to technical, allocative and economic efficiency of cumin production in North AcheferWoredaby providing empirical evidence from smallholder cumin producers.Therefore, the aim of this study gives better understanding on analysis of economic efficiency of cumin in North Acheferworeda of Amhara National Regional State by using extended efficiency measurement techniques.

1.3. Objectives of the Study

1.3.1. General Objectives

The general objective of this study was to assess the economic efficiency of cumin in North Achefer District.

1.3.2. Specific Objectives

In addition to the above general objective this studyassumed the following specific objectives. The specific objectives of the study were:

- ✓ To measure the level of technical efficiency of cumin production in the study area
- ✓ To measure the level of allocativeefficiency of cumin production in the study area
- ✓ To determine the economic efficiencies of cumin production in the study area.
- ✓ To identify the determinants of economic efficiencies of cumin in the study area.

1.4. Research Questions

This study made an attempt to address the following main research questions:

- ➢ Do institutional factors affect the efficiency of cumin producers in the study area?
- ➢ Do socioeconomic factors affect the efficiency of cumin producers in the study area?
- ➢ Do demographic factors affect the efficiency of cumin producers in the study area?
- ➢ What is the return to scale of smallholder cumin producers in the study area?
- ➢ What is the level of TE, AE and EE of cumin producers in the study area?

1.5. Scope and Limitations of the Study

Farmers in the study areaproduce a variety of crops ranging from annual food crops, cash crops and spice crops. Cereals, among food grains, are the dominant ones and spices are also next to cereals. This studyfocused on the analysis of EE of cumin producing farmers using stochastic frontier approach. It aims at also identifying the factors that affect the EE of cumin producer farmers by usingTobit model. The efficiency score of the stochastic frontier method were only relative to the best farm households in the sample, the inclusion of extra farms may reduce the efficiency scores (Coelli et al., 2005). Thus, the efficiency scores in this study are relative values of the best farmers in the study area. The findings of the study must be viewed in lights of some of the following potential limitations: (1) the study was conducted using cross-sectional data which does not capture inter-temporal differences in efficiency levels of households in a specific district, and (2)farmers do not keep records. As a result, they may face recalling problems of the past events. Thus, there was possibility of collecting wrong information during the survey time. Also farmers may be suspicious to give correct information on their income due to fear of income tax. So, all these limitations may adversely affect the reliability of the obtained results.

1.6. Significance of the Study

The measurement of efficiencies is a very important factor of productivity growth both in developing and developed countries. It is more so in developing agricultural economies where resources are meagre and opportunities for developing and adopting better technologies have lately started dwindling (Ali and Chaudhry, 1990). The measurement of efficiency (TE, AE and EE) has a very significant importance for the Ethiopian economy as a whole. It is used to differentiate the inefficient farm and to derive lessons about better production practices from more efficient farms. Hence, this study believed to play a significant role in providing useful information regarding economic inefficiencies in production and helps to identify those factors, which are associated with inefficiencies that may exist. Besides, the study gives insight and serve as a document for students and researchers interested in the topic to stimulate further investigations of the problem in the study area. Given the demographic pressure of Ethiopia, increasing total production of cumin through farmsize expansion is difficult (MOA, 2013). Thus, improving the efficiency of farmers so as to increase their productivity is a better option. The identification of the factors that determine the EE of cumin and determining the level of TE, AE and EE, has therefore, contribute to improve the farming practices of the studying area by giving relevant policy recommendations. Furthermore, given the fact that efficiency studies on cumin was not previously studied elsewhere, even outside Ethiopia, the results of this study will have a contribution to other developing countries.

1.7. Organization of the study

The thesis is organized into five chapters. The first of this study deals with introduction, statement of the problem, objectives of the study, and significance of the study. The second chapter deals with review of literature which includes theoretical,conceptual and analytical framework of and empirical studies made onefficiency in different countries. The third chapter of this study was deals research methodology including the descriptions of the study, types and sources of data,sampling design, data collection and methods of data analysis.Chapter four was deals with results and discussion of descriptive and econometric model results. Finally, conclusion and recommendations based on the results of the study arepresented in chapter five.

CHAPTER TWO

LITERATURE REVIEW

2.1. Concept of Efficiency

Efficiency is considered to be one of the most issues important in the production process. In economics, efficiency is commonly used in a variety of settings which includes aspects such as efficient price, efficient markets and efficient firms among others. It is measured by comparing the observed output against the feasible (frontier) output and to scarce resources being used in an optimal fashion. In economics, terms such as efficiency, productivity, technology growth and economic growth are very widely used and sometimes interchangeably. However, although there are similarities and linkages among them, they are not equivalent. The conceptualization and measurement of efficiency relies on the specification of a production function. The production function represents the maximum output attainable from the use of a given level of inputs. The production function describes production performance and productivity is the measure of it. Algebraically, productivity is defined as the ratio of the amount of output produced to the amount of resources used. However, efficiency is the ratio of the value of output produced to the cost of inputs used (Jema, 2008).

According to (Farrell, 1957), efficiency is measured by comparing the actually attained or real value of the objective function against what is attainable at the frontier. A producer is efficient if his/her goals are achieved and inefficient if he/she falls below his/her goal. It is a relation between end and means. Efficiency measures the amount to which the ends and means available to the unit and to the society are matched. Thus, technical inefficiency is costly; both to the producing unit under investigation and the society at large (Färe*et al*., 1985).Efficiency has several dimensions, two of which are TE and AE. TE is the extent to which the maximum possible output is achieved from give combination of inputs(Coelli *et al*., 1998). On the other hand, AE means that the firm is using resources in such combinations that the cost per unit of output for that rate of output is the least. According to Uri (2002), TE is defined as the proportional reduction in inputs possible for a given level of output in order to obtain the efficient input use. AE measures the ability to use the inputs in optimal proportions given their respective prices. The above two measures can be combined to give a measure of economic efficiency (EE). Notwithstanding, AE differs from TE, which reflects the ability of a firm to use the inputs in optimal proportions, given their respective price endowment levels and the availability of the production technology, where as TE refers to the ability to produce a given level of output with a minimum quantity of inputs under certain technology. Once again, TE and AE are then combined to give EE, which is sometimes referred to as overall efficiency (Coelli *et al.*, 1998).

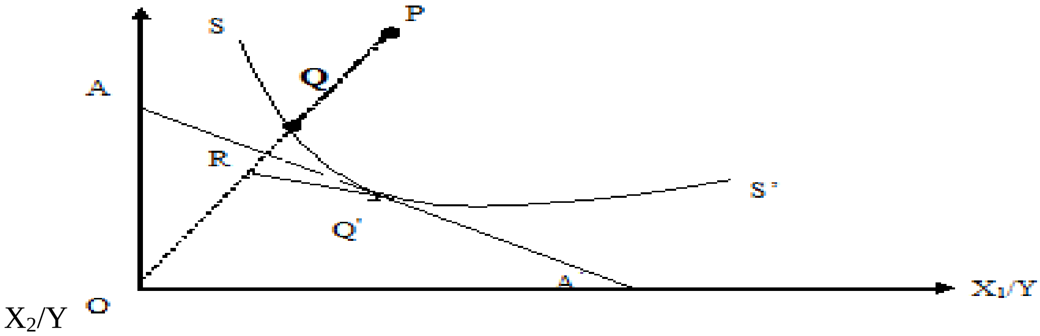
Economic efficiency combines both TE and AE. An economically efficient input-output combination would be on both the frontier function and the expansion path. Alternatively, EE refers to the proper choice of inputs and products combination according to their price relation or the ability of the firm to maximize profit by equating marginal revenue product of inputs to their respective marginal costs. If a farm has achieved both technicaland allocative efficiency levels of production, it is economically efficient and new investment streams may be critical for any new development (Farrell, 1957).

2.2. Measures of Production Efficiency

The traditional micro-economic theory, which deals with the behaviour of firms, presupposes full and efficient utilization of resources, perfect knowledge and free mobility of resources. There are two approaches of measuring efficiency: output oriented approach (referred to as primal approach) and input oriented approach (referred to as dual approach). In the primal approach the interest is by how much output could be expanded from a given level of inputs, hence known as output shortfall. Whereas in the input oriented approach the concern is the amount by which all inputs could be proportionally reduced to achieve efficient level of production, hence,known as input over use. Both measures will coincide when the technology exhibits constant returns to scale, but are likely to vary otherwise (Coelli *et al.*, 2005).

2.2.1. Input Based Measures of Efficiency

Farrell (1957) illustrated his idea about measuring efficiency using a simple example involving firms, which use two inputs (X_1 and X_2) to produce a single output (Y) under the assumption of constant returns to scale. In figure 1 below SS' is an iso-quant, representing technically efficient combinations of inputs, X_1 and X_2, used in producing output Q. SS' is also known as the best practice production frontier. AA' is an iso-cost line, which shows all combination of inputs X_1 and X_2 to be used in such a way that the total cost of inputs is equal at all points. However, any firm intending to maximize profits has to produce at Q', which is a point of tangency and representing the least cost combination of X_1 and X_2 in production of Q. At point Q' the producer is economically efficient.



Source:Coelli(1995)

Figure2.1 Input-oriented measures of technical and allocative efficiencies

The same figure (Figure 2.1) is employed to measure the technical, allocative and economic efficiencies. Suppose a farmer is producing his output depicted by isoquant SS' with input combination level of (X_1 and X_2). Production at input combination of point (P) is not technically efficient because the level of inputs needed to produce the same quantity is Q on isoquant SS'. In other words, the farmer can produce at any point on SS' with fewer inputs (X1 and X2), in this case at Q in an input-input space. The degree of TE of such a farm is measured as OQ/OP, which is proportional in all inputs that could theoretically be achieved without reducing the output. The technical efficiency (TE) of a firm is most commonly measured by the ratio:

$$TE=\frac{OQ}{OP} = 1 - \frac{QP}{OP} \qquad (2.1)$$

On the other hand, allocative efficiency measures the extent to which a firm uses the various factors in the best proportion given inputs and output prices. As a result, technically efficient farms operating at the isoquant may not necessarily be allocatively efficient, since allocative efficiency requires additional information on both inputs and output prices. In Figure 2.1, AA' represents input price ratio or isocost line which gives the minimum expenditure for which a firm intending to maximize profit should adopt. The same firm using (X_1 and X_2) to produce output with input combination at point P would be allocatively inefficient in relation to R. Its level of AE is represented by OR/OQ , since the distance RQ represents the reduction in production costs if the farmer using the combination of input (X_1 and X_2) was to produce at any point on AA', particularly at point R instead of P. The allocative efficiency (AE) of the firm operating at point P could be measured as the ratio:

$AE = \frac{OR}{OQ} = 1 - \frac{QR}{OQ}$ (2.2)

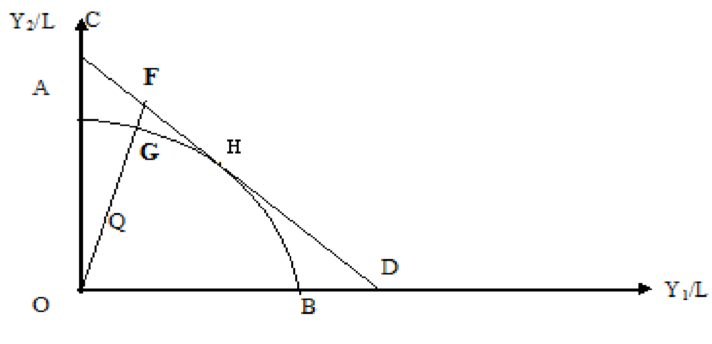
The products of the technical and allocative efficiencies measures provide the measure of overall economic efficiency. The total economic efficiency (EE) is defined to be the ratio:

$EF = (TE * AE) = \left(\frac{OQ}{OP}\right) * \left(\frac{OR}{OQ}\right) = \frac{OR}{OP}$ (2.3)

The above theoretical measures of efficiency assume the production function is known. However in practice, the isoquant is never known. Hence, these isoquant that represent the efficient points must be estimated from sample data.All three measures of efficiency are bounded between zero and one. This followsfrom interpretation of distance RP as the reduction in costs if a technically and allocatively inefficient producer at P were to become efficient (both technically and allocatively) at Q' (Coelli, 1995). Input-oriented technical efficiency measures address the question: "By how much can input quantities be proportionally reduced without changing the output quantities produced?" One could ask : "By how much can the output be proportionally expanded without changing the inputs quantities used?" is output-oriented measure.

2.2.2. Output Based Measures of Efficiency

In this perspective, efficiency is evaluated keeping inputs constant. Knowledge of the fully efficient production possibility curve as well as the iso-revenue line makes it possible to measure and interpret the level of EE. Output oriented measures can be illustrated by considering the case where production involves two outputs (Y_1 and Y_2) and a single input (L). The production possibility curve is represented by the curve AB in Figure 2, which represents technically efficient combinations of production of outputs Y_1/L and Y_2/L. The distance QG represents technical inefficiency (the technical inefficiency is the ratio, QG/OG). That is, the amount by which outputs could be increased without requiring extra inputs. If the input quantity is held fixed at a particular level, the technology can be represented by a production possibility curve in two dimensions as follows:



Source: Coelli et al.(1998)

Figure 2.2 Output-oriented measures for technical and allocative efficiencies

Hence a measure of output-oriented technical efficiency is the ratio:

$$TE = \frac{OQ}{OG} \quad (2.4)$$

The allocative efficiency (AE) of the firm operating at point F could be measured as the ratio:

$$AE = \frac{OG}{OF} \quad (2.5)$$

The economically efficient point is H where the marginal rate of product transformation equals the slope of the isorevenue line CD. Consider a firm situated at point Q. Its economic output efficiency ratio:

$$EE = \frac{OQ}{OG} * \frac{OG}{OF} = \frac{OQ}{OF} \quad (2.6)$$

The point of tangency between the iso-revenue line CD and the production possibility curve AB (at point H) represents the economically efficient method of production, which is 100% technically and allocatively efficient (Coelli et al., 1998). Again, all these three measures are between zero and one.

2.3. Methods of Efficiency Measurement

The analytical framework in the previous part provides the necessary theoretical efficiency measures that should be calculated at the firm level. However, it is short in offering any practical techniques to estimate or calculate these measures. In fact, once the theoretical framework was set by Farrell (1957), the techniques for estimation of efficiency did not follow immediately. These efficiency measurements basically are carried out using frontier methodologies, which shift the average response functions to the maximum output or to the efficient firm. These methodologies are broadly categorized under two frontier models; namely parametric and non-parametric. The parametric models are basically estimated based on econometric methods and the non-parametric model, often referred to as Data Envelopment Analysis (DEA), involves the use of linear programming method to construct a non-parametric 'piece-wise' surface (or frontier) over the data (Coelli et al., 1998). Efficiency measures assume that production function of the fully efficient firm is known. But this is different in practice, and the efficient isoquant must be estimated from the sample data. Farrell (1957) suggests the use of either (1) a non-parametric piece-wise linear convex isoquant constructed in such a way that no observed points should lie to the left or below it, or (2) a parametric function such as Cobb-Douglas production function.

2.3.1. Non-Parametric Frontier Models

The non-parametric method, first developed by Charnes et al. (1978) is called as DEA. The aim of the method is to calculate the coefficients for input-output matrix that will in turn define a “frontier envelopment surface”. The DEA frontier is both non-parametric and non-stochastic since it does not impose any a priori parametric restrictions on the underlying frontier technology and doesn't require any distributional assumption for the technical inefficiency term. Therefore, the model avoids the imposition of unwarranted structures on both the frontier technology and the inefficiency component that might create distortion in the measurement of efficiency (Färe et al., 1985).The common feature of estimation techniques based on Farrell’s (1957) efficiency definition is that the information is extracted from extreme observations in the sense of TE, to form the best practice production frontier.

2.3.2. Parametric Frontier Models

The parametric approaches try to estimate the efficiency scores by estimating an efficient frontier. Thus, the difference between parametric and non-parametric approach is that while nonparametric approaches try to calculate the efficiency scores directly without estimating any frontier, the parametric model estimates the efficient frontier by estimating the parameters of frontier, and then measures the distance of observed input-output data to the estimated frontier.

The parametric approach depends on the assumptions about the mathematical form of production function. So, the conventional assumption of neoclassical production theory about the shape of production frontier is maintained in parametric approaches. Thus parametric approaches, unlike the non-parametric ones, are subject to any criticisms directed to functional assumptions of the neoclassical production theory. In fact, the criticisms directed to non-parametric approaches for ignoring the economic theory stems from this point. The followers of parametric approach accuse the followers of non-parametric approach with ignoring the conventional production theory, while the followers of parametric approach accuse the others with "torching" the data bymaking a priori impositions about the functional form. The debate is still going on and it is impossible to give a precise reason to prefer one of the approaches to the other. The parametric approach is generally preferred by economists, while the champions of non-parametric approaches are generally from management and operations research (Hasan, 2006).Parametric frontier model can further be classified into deterministic and stochastic frontier methods. The deterministic model assumes that any deviation from the frontier is due to inefficiency, while the stochastic approach allows for statistical noise.

2.3.2.1. Deterministic Frontier Model

According to Aigner and Chu (1968) a Cobb-Douglas production function for a sample of Nfirms can be specified as:

$$\ln(Y_i) = \ln f(X_i; B_i) - U_i \qquad (2.7)$$

TE_i = exp ($-u_i$); where, i = 1,2,....N

Since $TE_i \leq 1$ should hold, the restriction on $u_i \geq 0$ is necessary.

Where Y_i is the output of the i^{th} firm; X_i is the vector of input quantities used by the i^{th} firm; β_i is a vector of unknown parameters to be estimated; f (.) denotes an appropriate function (Cobb Douglas); and u_i is a non-negative variable representing the inefficiency in production.

The limitation of this model is that, it treats random components (like measurement error, bad weather, etc.) as part of inefficiency. Coelli (1995) argues that one of the criticisms of the deterministic approach is that no account is taken of the possible influences of measurement errors and other noises up on the shape and positioning of the estimated frontier. The stochastic models allow for random deviations from efficient frontier.

2.3.2.2. Stochastic Frontier Model

Aigner et al. (1977) and Meeusen and Broeck (1977) introduced simultaneously the idea of composed error to overcome the problems with the deterministic models in the crosssectional context. The idea was rather simple, but its implementation led to the use of complicated econometric procedures. They added a symmetric while noise term to the deterministic model to capture the effects of factors other than technical TE on production procedure. Their model for single output can be represented by:

$$\ln Y = \beta_O + \sum_{n=1}^{\infty} \beta_n X_{ni} + V_i - U_i \qquad (2.8)$$

Here v_i is an independently and identically distributed symmetric noise component, while u_i denotes non-negative technical inefficiency term. An important assumption about vi is that it is independently distributed from u_i. The other advantage of the SFPF over the former (deterministic) is that the estimation of standard errors and tests of hypothesis is possible, which the deterministic model fails to fulfill because of the violation of the Maximum Likelihood regularity conditions (Coelli, 1995).SFPF can be estimated using Maximum Likelihood (ML) or OLS method. The OLS is advised to use, for its simplicity in analysis. However, ML method is asymptotically efficient than OLS. Given this rational ML method is preferred than OLS whenever possible.

2.3.3. Stochastic Frontier Efficiency Decomposition

All the models discussed so far are only appropriate for measuring TE peruse. The measurement of TE, AE and EE can only handle, stochastic frontier framework, through the efficiency decomposition technique. The stochastic decomposition methodology was proposed by Bravo-Ureta and Rieger (1991), which was an extension of the model introduced by Kopp and Diewert (1982) to decompose cost efficiency (CE) into TE and AE measures. Stochastic efficiency decomposition is generally based on the duality between production and cost functions.Bravo-Ureta and Rieger (1991) utilize the level of output of each firm adjusted for statistical noise, observed input ratios and the parameters of stochastic frontier production function (SFPF) to decompose EE into TE and AE. The parameters of the SFPF are actually used to derive the parameters of dual cost function. Let redefined in its original form of Aiger et al. (1977) and Meeusen and Van den Broeck (1977) as:

$$\ln(Y_i) = f(X_i;\beta_i) + V_i - U_i \quad (2.9)$$

If v_i is now subtracted from both sides of equation (9), we obtain

$$Y_i^* = f(X_i;\beta_i) - U_i = Y_i - V_i \quad (2.10)$$

where Y_i^* is the i^{th} firm's observed output adjusted for the statistical noise captured by v_i, X_i is the vector of input quantities used by the i^{th} firm; β is a vector of unknown parameters to be estimated; f (.) denotes functional relationship (Cobb-Douglas); and u_i is a non-negative variable representing the inefficiency in production. The adjusted output Y* is used to derive the technically efficient input vector, X^t. The technically efficient input vector for the i^{th} firm, X_{it}, is derived by simultaneously solving equation (2.10) and the observed input ratio $x_1/x_i = k_i$ where k_i is equal to observed ratio of the two inputs in the production of Y_i^*. The technically efficient input vectors form the basis for deriving the TE measures by taking ratios of the vector norms of the efficient and observed input quantities while the adjusted output is used to derive AE and EE employing the dual cost frontier function that is analytically derived from the SFPF.

2.4. Empirical Studies on Efficiency

2.4.1. Empirical Studies on Efficiency from outside Ethiopia

Ali et al. (2012) estimated the EE of wheat and faba bean production in Northern State Sudan using the SFPF and cost functions (CF). A sample of 120 farmers from Dongola locality in the North and Ed-abba locality in the South of the State in 2004/05 winter season were selected using a randomized multi-stage stratified sampling technique. SFPF and CF were used to estimate the EE of farmers. The results showed that the mean TE of wheat were 0.75 and 0.66 in Dongola and Ed-abba, respectively, while for faba bean they were 0.65 and 0.71, the overall mean AE of wheat in the two localities were 0.72 and 0.68, whereas, they were 0.86, 0.84 for faba bean. The predicted overall mean of EE that estimated as inverse of their CE of wheat were 0.41 and 0.45 in the two localities, while in faba bean production they were 0.57 and 0.62 in Dongola and Ed-abba, respectively. It indicates that the EE of faba bean is better than wheat.

Essilfie et al. (2011) estimated the levels of TE in small scale maize production in the Mfantseman Municipality of Ghana using the stochastic frontier approach. The study also attempted to determine some socio-economic characteristics and management practices which influence TE in maize production. Finally, the marginal physical products, average physical products, relative efficiency of resource use and the returns to scale of input use were calculated. The results indicated that the mean TE of small scale maize production in the study area was 58%; however, this ranged from 17% to 99%. In addition, the study estimated return to scale to be 1.49 indicating increasing returns to scale of maize production in the study area.

A study conducted by Ogunniyi (2011) employed a stochastic frontier profit function to measure profit efficiency among maize producers in Oyo State, Nigeria. A multi-stage random sampling technique was used to select 240 maize producers. The results showed that profit efficiencies of the farmers varied widely between 1% and 99.9% with a mean of 41.4% suggesting that an estimated 58.6% of the profit is lost due to a combination of both technical and allocative inefficiencies in maize production. From the inefficiency model, it was found that education, experience, extension and non-farm employment were significant factors influencing profit efficiency. This implies that profit inefficiency in maize production can be reduced significantly with improvement in the level of education of sampled farmers.

Khai et al. (2008) had undertaken efficiency measurement to investigate the efficiency levels of farmers who got involved with agricultural activities. A major task of efficiency analysis is to identify determinants of efficiency levels. As the empirical studies mentioned, farmers in developing countries are unsuccessful in taking advantage of the potential of technology making inefficient decisions. Therefore, the study made an effort to estimate TE, AE and EE of soybean farmers in the Mekong River Delta of Vietnam and identified its determinants. The result showed average levels of TE, AE and EE to be 74%, 51% and 38%, respectively.

Andreu (2008) applied the concept of EE on Kansas farms. In his study, he considered capital, labor, land, and purchased inputs. The data for this study were of a 10 year (1998-2007) on the farms belonging to Kansas farm management association. DEA techniques were used to construct a non-parametric efficiency frontier and calculate TE, AE, and EE for each farm and each year. None of the farms in the data sample were TE, AE or EE in all 10 years of the study. On his study, Andreu (2008) confirmed that larger farms were more efficient than smaller ones.

Ephraim (2007) using plot and farm level data, had investigated TE variation among smallholder maize farmers and identified sources of inefficiency in Malawi. His result indicated that, smallholder maize farmers in Malawi were inefficient; the average efficiency score was 46.23% and 79%, respectively. The results of the study revealed that inefficiency declines on plots planted with hybrid seeds and for those controlled by farmers who belong to households with membership in a farmers club or association.

Hasan (2006) used a stochastic frontier approach to estimate a self-dual Cobb-Douglas production function which gave CE, returns and EE of maize production compared to Boro rice at the Sadarupazila of Dinajpur and Panchagarh of Northern Region of Bangladesh. The growth rate of maize in the country and constraints to maize production at farm level was also emphasized. The sample size of the study was 100 equally from each district. All the farmers used hybrid seeds for maize cultivation with an average yield of 6.27 ton/ha, which was higher in Dinajpur (6.35 ton/ha) compared to Panchagarh district (6.18 ton/ha). The returns to scale of the selected inputs were 0.72 and 0.68 for Dinajpur and Panchagarh respectively. The TE was found to be, on an average, 84% and 80% at Dinajpur and Panchagarh.

Bravo and Pinheiro (1997) conducted on peasant farming efficiency in Congo, the mean value of TE, AE and EE were 70%, 44% and 31%, respectively. These results suggested that substantial gains in output and/or decreases in cost could be attained given the existing technology. Data for this study was collected from 60 peasant farmers in Dajabon region, which is situated in the North West corner of the Dominican Republic. In their study, they used ML techniques to estimate a Cobb-Douglas production frontier, which was then being used to derive its corresponding dual cost. Finally, the study suggested that policymakers should foster the development of medium size farms, while promoting contract arrangements between peasant farmers and agribusinesses.

2.4.2. Empirical Studies on Economic Efficiency from Ethiopia

A recent study by Kifle (2014) made an attempt to measure the level of TE, AE and EE of maize production and to identify factors affecting them in the study area. The study was conducted using cross-sectional data collected from 124 sample households from BakoTibe District, OromiaNational Regional State. Stochastic production frontier model was used to estimate TE, AE and EE levels, whereas Tobit model was used to identify factors affecting efficiency levels. The results indicated that there was significant inefficiency in maize production in the study area. The mean TE, AE and EE of sample households were 82.93%, 66.03% and 54%, respectively. Results of the Tobit model reveal that age, off/non-farm activities, amount of land owned and perception on agricultural policy had a significant positive effect on TE and sex of household head had less significant effect or negative effect on TE as expected. Education, frequency of extension visit, perception on agricultural policy and livestock holding had positive significant effect on AE while age of household head, off/non-farm activities, amount of land owned, credit utilized and perception on agricultural policy were found to have positive effect on EE.

Solomon (2012) made an attempt to measure the level of TE, AE and EE of wheat seed production and to identify factors affecting them in the study area. The study was conducted using cross-sectional data collected from 150 sample households from WombermaWoreda of West Gojjam zone. Stochastic production frontier model was used to estimate TE, AE and EElevels, whereas Tobit model was used to identify factors affecting efficiency levels. The results indicated that there was significant inefficiency in wheat seed production in the study area. Accordingly, the mean TE, AE and EE of sample households were 79.9%, 47.7% and 37.3%, respectively. Results of the Tobit model reveal that interest in wheat seed business and total income positively and significantly affect TE while total expenditure had a negative and significant effect. Education level and livestock ownership had a significant positive impact on AE and economic EE while land ownership and total cultivated land had a significant negative effect on AE and EE, respectively.

Nejuma (2012) investigated TE, AE and EE and identified factors that caused differences in EE of potato producing farmers of Shashemene district of West Arsi Zone. The study used cross sectional data collected in 2011/12 production year from 150 sample households. Cobb-Douglas functional form of stochastic frontier model was used to estimate the efficiency of potato production. The estimated frontier model showed that the mean TE, AE and EE of potato producer farmers were 74%, 45% and 33%, respectively. Among the farm specific socioeconomic and institutional factors hypothesized to affect the level of EE: age, access to credit and training were found to have positive and significant impact on EE of potato production.

Hassen (2011) calculated the production efficiency of the mixed crop-livestock farmers in two districts of North Eastern Ethiopia. Cross-sectional data were used to analyze the performance of mixed crop and livestock production system and determinants of production efficiencies. The non-parametric method DEA was employed to measure production efficiency. The mean TE, AE and EE of the household calculated from non-parametric approach of DEA variable returns to scale were 55%, 72% and 40%, respectively, indicating the existence of substantial inefficiency of TE, AE and EE of production in the study area.

Essa (2011) estimated the level of EE of smallholder major crops production in the central highlands of Ethiopia. Cross-sectional data from a baseline survey conducted by the ICRISAT and EIAR were used. Using DEA approach, the study established that smallholder farmers in the study areas were TE, AE and EE inefficient with mean TE, AE and EE scores of 0.79, 0.43 and 0.31, respectively.Furthermore, a two- limit Tobit regression model results revealed that while family size, farming experience, credit access, walking distance to the nearest main market, and total own land cultivated during the long rainy season affected TE positively and significantly; age of household head was found to have a negative and significant influence on TE. The results also showed that whereas EE was positively and significantly affected by family size, farming experience and membership to associations; for household heads having a role in their community, contributed negatively and significantly to EE.

Jema (2008) in his study on EE of vegetable production, Ethiopia, used both parametric and non-parametric approaches. The result revealed that there was similarity in the estimates of efficiency in both methodologies. He used the two stage approach in determining factors affecting efficiency. He also compared the efficiency of the whole farm with vegetable production, out of which the level of EE was 0.53 and 0.43, respectively. To him, this difference might be attributed to limited access to capital markets, high consumer spending and large family size. The mean TE, AE and EE, estimated by the non-parametric DEA, were 91%, 60% and 56 % respectively. An economic analysis based on Tobit model indicated that asset, off/non-farm income, farm size, extension visits and family size were the significant determinants of TE,whereas asset, crop diversification, consumer expenditures and farm size had significant impact on AE and EE.

2.5. Conceptual Framework

Figure 2.3 shows the interaction between various factors that were considered to have a various degree and direction of effect on the level of EE of cumin production. Efficiency of production was determined by the host of socio-economic and institutional factors (Jema, 2008). These factors directly/indirectly affect the quality of management of the farm's operator and, therefore, are believed to have effect on the level of TE, AE and EE of farms. According to Bakhsh (2007), a range of factors like distinctiveness of farms, management, physical, institutional and environmental aspects could be the cause of inefficiencies in the production process of the farmers.

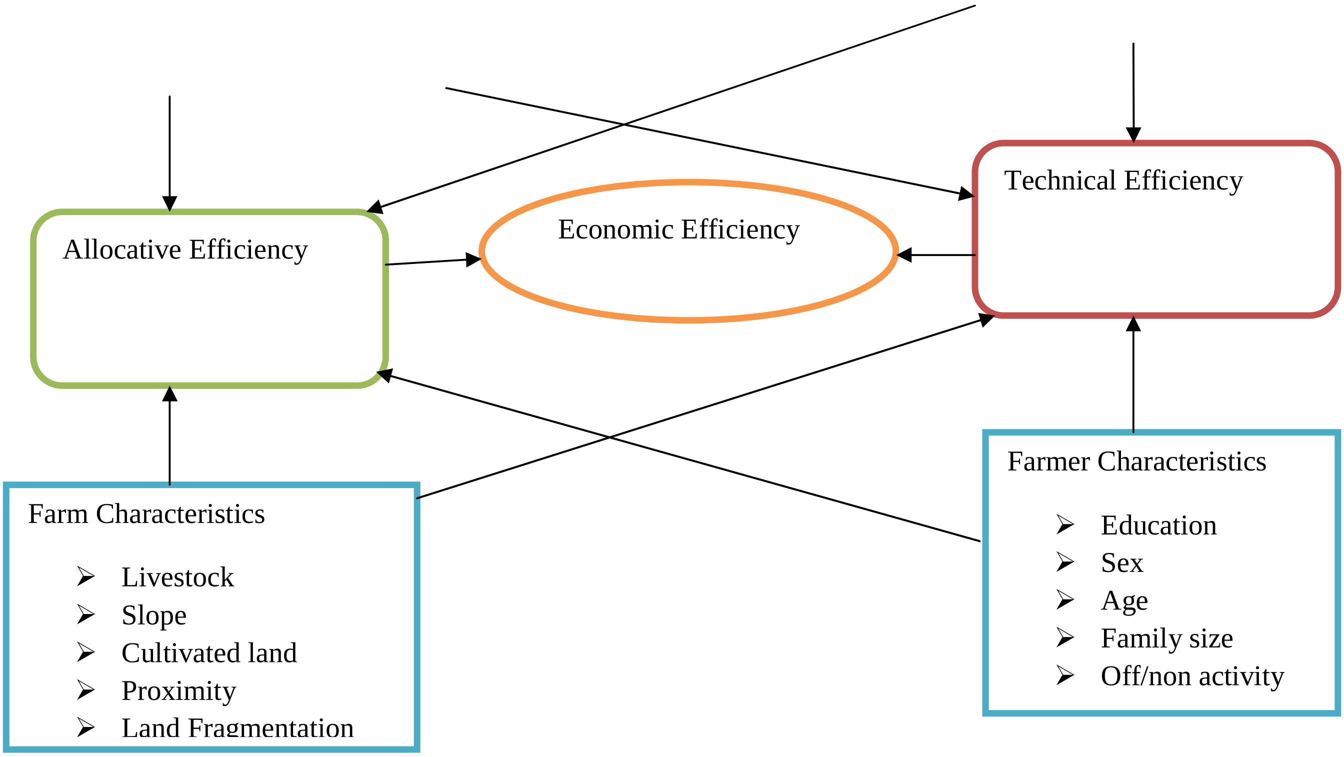
Environmental factors such as perception on weather condition and flood can affect resource use efficiency in crops production. Hasan (2006) indicated that there may be a negative interaction between some agricultural practices and the environment. Levels of producer's education influence the producer's management capacity. Ajibefun (2002) indicated that education level of farmers and farming experience are important determinants of efficiency which can be incorporated into the agricultural policy. The farmers with more education, more land and farm tools are more likely to adopt new technologies. In addition, family size, per capita net income, and family members operating as village leaders are positively related to their efficiency.

Policy and Institutional Factors

- Perception on agricultural policy
- Extension
- Credit Utilization
- Training

Environmental Factors

- Environmental Hazard
- Weather Condition



Source: Adapted from author KifleDegefa (2014)

Figure 2.3 Conceptual framework of EE in cumin production

Policy and institutional factors such as perception on agricultural policy, extension, training, credit utilization and input accesses can have significant effect on the resource use efficiency of cumin production. Extension and access to credits are important policy and institutional variables that positively influence efficiency (Tchale, 2009).

Level of producer's education and age influences the producer's management capacity. The farmers with more education, more land and farm tools are more likely to adopt new technologies. In addition, family size, sex, and family members operating as village leaders are positively related to their production efficiency. Ajibefun (2002) indicated that education level of farmers and farming experience are important determinants of efficiency which can be incorporated into the agricultural policy. Efficiency variations between farms can also be explained by the farm location, slope and livestock. Farm location is important since farms may operate under different climate or altitude conditions and different plot slope and land fragmentation. Farm related variables are important because in most farming systems in sub-Saharan Africa there are significant variations in terms of plot-level biophysical and soil chemical characteristics (Tchale, 2009).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Description of the Study Area

3.1.1. Location and Size

The study area, North Acheferdistrict is located in West Gojjam Zone of Amhara National Regional State in theNorthern part of Ethiopia. The study area borderline withNorth Gonder Zone in west, Bahir Dar Zuriadistrict in east, on the north by Lake Tana, and on south-east by Mecha; the lesser Abay River defines the woreda’s eastern boundary.The administrative center is Liben town. The woreda is situated at about 534 km North West of Addis Ababa and 34km west of Bahir Dar, the capital of city Amhara regional state, respectively. Astronomically, the woreda is located between 110^{0} 29’ 31’’ N and 110^{0} 53’ 4’’ N latitude and 360^{0} 39’ 0’’ E and 370^{0} 12’ 53’’ E longitudes. The study area covers 118,400 hectares, 27 kebels, out of which 24 are rural kebeles and the remaining 3 are urban kebeles (Figure 3.1).

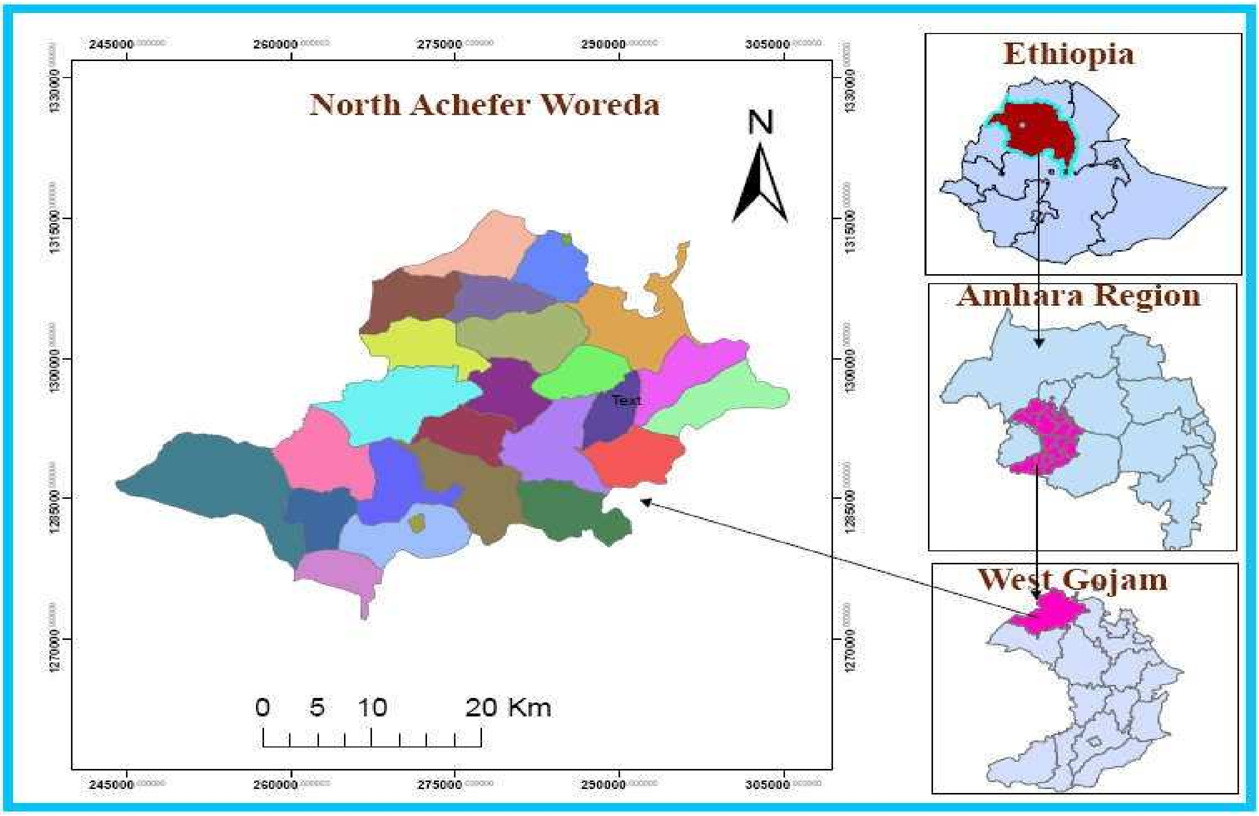


Figure3.1Location oftheStudyArea

3.1.2. Topography and climate

According to the North Achefer(2012) the altitude of the District ranges from 1215 meters to 2691 meters above sea level. Highly elevated areas are found on the South western part of the study area. The low elevated areas are found in the west and south western parts. On the other hand, plateaus are located in the central and eastern part of the study area.

Climate determines both the type and efficiency of agricultural activities performed in a given area. There are different climatic elements that characterize the climatic types of a given area. In most studies, however, temperature and rain fall are most commonly used to determine the climatic condition of an area. The temperature and rain fall of the area are used here to describe the climate of the study area. The study area has no meteorological station and data from the nearby station are used.

Temperature is the most fundamental element of climate. The study area has average annual maximum and minimum temperature 22.5^{o}C and 16 ^{0}C respectively. The highest and the lowest temperatures were recorded in April and January respectively. The mean annual range of temperature was about 6.5^{0}C implying the temperature of the area was relatively less variable.The study area gets rain fall mainly in the summer. The average annual rainfall was about 1409 mm. The highest rain fall has been recorded in the study area, in June, July and August. The lowest rain fall occurs in the area from December to March. Generally, rain fall is less variable.The distribution of natural vegetation determines the climatic conditions of an area. In turn climatic maps indicate vegetation distribution. The area has once been covered by dense forest cover has been removed and replaced by cultivation field. It was changed because of demand for fuel wood and charcoal, house construction triggered by population pressure. The only forest cover in the area is found mainly in man-made forest areas and Churches. Eucalyptus globules (bahirzaf) are the most dominant forest type.

3.1.5. Population and Socioeconomic Conditions of the Study Area

According to the (CSA, 2007) report, the total population of the North Acheferworeda was about 173,211 people, out of which 88,655 are males and 84,556 are females. About 161,479 people live in rural kebeles and 11,732 live in urban kebeles. According to the office of the woreda statistics currently the population of the woreda is about 203,335, and from this total population male account 103,767 and the remaining 99,568 are females. The number of people in urban and rural areas is 18,434 and 184,901 people respectively.

Cumin is the main cash crop and livelihood source of the people of the study area. Cumin crop production is the most important agricultural activity. However, cumin crop production is rainfall dependent. The main crops grown widely in the area are 'teff', barely, wheat, beans, sorghum and maize, even spice crops like cumin. According to the woreda agricultural and rural development office out of the crops grown in the study area, cumin crop gives the first highest area coverage in hectare. Livestock production is also considered as the vital agriculture activity of the area. It is an important supporter of the cumin crop production.

3.2. Research Design and Approach

Descriptive and causal research designs were used as the main type of research for the investigation. In order to accomplish the proposed research with respect to the objectives and the nature of research questions of the study, both qualitative and quantitative data collection and analytical techniques were employed. Therefore, the overall configuration of the study consists of both qualitative and quantitative data. Quantitative data analysis is all about quantifying relationships between variables, production and economic efficiency of cumin and factors affecting such as sex, age, family size, level of education, sources of income etc. Qualitative approach used in conjunction with quantitative approaches to strengthen quantitative data. Therefore, a mixed research approach is adopted in this study.

3.3. Sampling Techniques and Sample size determination

In this study, a combination of both purposive and multiple stage random sampling techniqueswere employed to draw an appropriate sample households. NorthAchefer district was purposivelyselected because of the presence of large number of cumin producing households and its extentof production in the area. In the first stage, three kebeles were selected randomly having higherarea under cumin and prepare list of cumin producers along with area under cumin. In the secondstage, divide these producing sample households into male and female headed households.Finally, from 1436 households who cumin producers, about 122 sample households wereselectedrandomly using probability proportionality size following a simplified formula providedby Yamane (Yamane, 1967).Accordingly, the required sample size at 95% confidence level with degree of variability of 5%and level of precision equal to 9% are used to obtain a sample size required which represents atrue population.

$$n = \frac{N}{1+N(e^2)} \qquad (3.1)$$

Where, n = sample size, N = Population size and e = level of precision considered (9%).

Accordingly, the distribution of sample size with the size of the kebeles is presented in Table 3.1.

Table 3.1 Sample households by kebeles

	Total cumin producing household heads		Sample Households Head		Total
Kebeles	Male	Female	Male	Female	Sample
Kongeree	602	58	46	4	50
LibenZuria	410	62	31	5	36
Dembola	424	47	32	4	36
Total	1436	167	109	13	122

Source: Own sampling design (2017)

3.4. Data Collection Techniques

A. Primary Data Collection

The research was accomplished using primary and secondary data sources. The primary data necessary to achieve the designed objectives were obtained through different techniques such as field observation, focus group discussion, from key informants and structured questionnaires (both close ended and open ended questions) and interview with woreda agricultural experts, kebele leaders and Development Agents.This field observation was helpful to acquire useful information which would have been difficult to collect through the questionnaire and other methods of data acquisition.

Household survey: was a typical method to collect primary data from the sample households. A structured questionnaire that has involved both closed ended and open ended questions was prepared and used to generate data from the respondents. As farmers in the area are speaking Amharic, the questionnaire was translated into the local language to make the question simple, clear and understandable to the farmers/respondents. The questionnaires were handled by high school graduate enumerators. Prior to implementing the survey, the questionnaire was used to train enumerators and tested for their clarity. Amendments were made to the questionnaires based on the feedbacks. Household survey was conducted through face to face interview of the respondent and enumerators. Household heads were appropriate respondents for the questionnaires designed for the survey.

B. Secondary Data Sources

The main sources of secondary data and information for this study were published and unpublished documents. These were books, articles, proceedings, journals, scientific reports, Ministry of Agriculture (MoA), Zonal and*woreda*annual reports on production and economic efficiency of cumin, and population were considered to be very vital to the study.

3.5. Methods of Data Analysis

To address the objectives of this research, both descriptive statistics and econometric methods of thedata analysis wereemployed. Descriptive statistics such as mean, maximum,minimum, standard deviation, frequency and percentage valueswere used tocharacterize the farming system of the study area. This study was analyzed by the stochastic frontier model than data evolvement analysis because stochastic frontier model was used when the study was in uncontrolled environment. Econometric analysis such as the stochasticfrontier approach was used to estimate the level of cumin production efficiency and a Tobitmodel was used to identify factors that affect the efficiency level of the farmers. This is because,in the context of developing world where random errors (measurement error, weather and naturaldisaster) are common, stochastic frontier production function is a relatively better measure of efficiency (Coelli, 2005). Moreover,a tobit model is more appropriate when the dependent variable is bounded between 0 and 1(Greene, 2003).

3.5.1. Specification of the Econometric Models

3.5.1.1.1. Efficiency Measurement

The prime objective of this study is to estimate and to identify the various determinants of TE, AE and EE in cumin production among smallholder farmers. To these ends, stochastic frontierproduction model was adopted.The stochastic frontier production function was autonomously developed by Aiger et al., (1977)and Meeusen and Van den Broeck (1977). It was used for its key features that the disturbanceterm is composed of two parts, symmetric and a one sided component. The symmetriccomponent captures the random effect outside of the control of the decision maker includingstatistical noise (such as weather, topography, and measurement error), etc. which are uncontrolledand exogenous to the farmer contained in every empirical relationship, particularly those basedon cross-sectional household survey data. The one sided component captures deviations from thefrontier due to inefficiency. Besides, the technique is consistent with most of the agriculturalproduction efficiency studies (Getu et al., 1998; Olarinde et al., 2008). Hence, economicefficiency measures obtained from stochastic frontiers are expected to reflect the true ability ofthe farmer given the resources.The assumption that all deviation from the frontier are associated with inefficiency, as assumedin data evolvement analysis, is difficult to accept, given the inherent variability of agricultural production due to a lotof factors like weather, pests, diseases, etc. (Coelli, 1995). Furthermore, smallholder farmers inEthiopia in general and in the study area in particular are characterized by low level of educationand keeping of records is thus non-existent. Moreover, there is high variability of agriculturalproduction due to weather fluctuations. Therefore, within the stochastic frontier framework, thestochastic efficiency decomposition methodology is chosen as more appropriate for this study.

Following Aiger et al. (1977) and Meeusen and Van den Broeck (1977), the general functionalform of stochastic frontier model for this study was specified as follows:

$$Y_i=f(X_i;B_i)+\varepsilon_i \qquad (3.2)$$

Where i = 1, 2, 3,..., n; Yi represent the observed output level of the i^{th} sample farmer; f(Xi; β) isconvenient frontier production function (e.g. Cobb-Douglas or trans log); Xi denotes the actualinput vector by the i^{th} farmer; β stand for the vector of unknown parameters to be estimated; ε_i isa composed disturbance term made up of two error elements (vi and ui) and n represents thenumber of farmers involved in the survey.

Stochastic frontier functional approach requires a priori specification of the production functionto estimate the level of efficiency. Among the possible algebraic forms, Cobb-Douglas andtrans- log functions have been the most popularly used models in the most empirical studies ofagricultural production analysis. Some researcher argue that Cobb-Douglas functional form hasadvantages over the other functional forms in that it provides a comparison between adequate fitof the data and computational feasibility. It is also convenient in interpreting elasticity ofproduction and it is very parsimonious with respect to degrees of freedom.

According to Coelli (1995), the Cobb-Douglas functional form has most attractive feature whichis its simplicity. A logarithmic transformation provides a model which is linear in the logs ofinputs and hence it lends itself to econometric estimation. Moreover, trans-log productionfunction is more complicated to estimate having serious estimation problems. One of theestimation problems is as the number of variable inputs increases; the number of parameters tobe estimated increases rapidly. Another problem is the additional terms require cross products ofinput variables, thus making a serious multi-collinearity and degrees of freedom problems.

Even through Cobb-Douglas model assumes unitary elasticity of substitution, constantproduction elasticity and constant factor demand; if the interest is to analyze the efficiencymeasurement and not analyzing the general structure of production function, it has adequaterepresentation of technology and insignificant impact on measurement of efficiency (Coelli etal., 2005). When farmers operate in small farms, the technology is unlikely to be substantiallyaffected by variable returns to scale (Coelli, 1995). Moreover, Cobb-Douglas productionfunction has been employed in many researches dealing with efficiency (Sharma et al., 1999;Arega and Rashid, 2005; Hasan, 2006; Jema, 2008; Kareem et al., 2008; Kifele, 2014). Therefore, it was alsobeadopted for this study. The linear form of Cobb-Douglas production functions for this study is defined as:

$$lnY_i = \beta_0 + \sum_{j=1}^{6} \beta_j X_{ij} + \varepsilon_i \quad (3.3)$$

$\varepsilon_i = v_i - u_i$

Where ln denotes the natural logarithm; j represents the number of inputs used; i represents thei^{th} farm in the sample; Y_i represent the observed cumin output of the i^{th} sample farmer; X_{ij}denotesj^{th} farm input variables used in cumin production of the i^{th} farmer; β stands for the vector ofunknown parameters to be estimated;ε_i is a composed disturbance term made up of two errorelements (v_i and u_i). The symmetric component (v_i) is assumed to be independently andidentically distributed as N (0, σ^2_v).

Aigner et al. (1977) proposed the log likelihood function for the model in equation (3.3)assuming half normal distribution for the technical inefficiency effects (u_i). They expressed thelikelihood function using λ parameterization, where λ is the ratio of the standard errors of thenon-symmetric to symmetric error term (i.e. $\lambda = \sigma_u/\sigma_v$). However, there is an association betweenγ and λ. The reason is that λ could be any non-negative value while γ ranges from zero to oneand better measures the distance between the frontier output and the observed level of outputresulting from technical inefficiency. According to Bravo and Pinheiro (1997) gamma (γ) can beformulated as:

$$\gamma = \frac{\Lambda^2}{1+\Lambda^2} \quad (3.4)$$

The parameter γ measures the discrepancy between frontier and observed levels of output and isinterpreted as the total variation in output from the frontier attributable to technical inefficiency.It has a value between zero and one. The value of zero indicates that the non-negative randomvariable, u_i is absent from the model while the value of one shows the absence of statistical"noise" or exogenous "shocks" from the model and hence low level of farm's productioncompared to the "best" practice (the maximum output) of the other farm that is totally a result offarm specific inefficiency. Likewise, the significance of σ^2 indicates whether the conventionalaverage production function adequately represent the data or not.

In fact, in this study the likelihood ratio test conduct to select the appropriate functionalform that best fits the data. The value of the generalized likelihood ratio (LR) statistic to test thehypotheses that all interaction terms including the square specification is equal to zero (H_0:β_{ij}=0) would be calculated as follows:

$$LR = -2(LC-LT) \qquad (3.5)$$

Where: LR= Generalized log-likelihood ratio;

LC = Log-likelihood value of Cobb-Douglas frontier; and

LT = Log-likelihood β value of Trans-log frontier.

This value is then compared with the upper 5% point for the χ^2 distribution and the decision wasmade based up on the model result. If the computed value of the test is bigger than the criticalvalue, the null hypothesis will be rejected and the trans-log frontier production function wouldbetter represent the production technology of farmers.

Assuming that the production function in equation (3.3) is self- dual (e.g. Cobb-Douglas), thedual cost function of the Cobb-Douglas production function can be specified as:

$$\ln Ci = \alpha_0 + \alpha_j \ln Y^* (3.6)$$

Where i refers to the i^{th} sample farm; j is number of input; C_i is the minimum cost of production; W_i denotes input prices; Y* refers to farm output which is adjusted for noise vi and α's are parameters was estimated.

Sharma et al. (1999) suggests that the corresponding dual cost frontier of the Cobb-Douglas production functional form in equation (3.2) can be rewritten as:

$$C_i = C(W_i, Y^*; \alpha) \qquad (3.7)$$

The economically efficient input vector of the i^{th} firm X_i^e is derived by applying Shepard'sLemma (Arega and Rashid, 2005, Kifle, 2014) and substituting the firms input prices and adjusted outputlevel, a system of minimum cost input demand equation can be expressed as:

$$\frac{\partial Ci}{\partial Wi} = X_i^e(Wi, Y^*; \alpha)(3.8)$$

The minimum cost is derived analytically from the production function, using the methodologyused in Arega and Rashid (2005) and Kifle(2014). Given input oriented function, the efficient cost function canbe specified as follows:

$$Min \sum_{X} C = \sum_{j=1}^{7} X_j W_j$$

Subjectto $Y_i^* = \hat{A} \prod X_j^{\grave{\beta} j}$ (3.9)

Where, $\hat{A}$= Exp(β_0)

The solution for the problem in the above equation is the basis for driving dual cost frontier. All the parameters are known; hence we can calculate the minimum (efficient) cost ofproduction. We can define the farm-specific technical efficiency in terms of observed output (Y_i)to the corresponding frontier output (Y^*) using the existing technology.

$TE_i = \frac{Y_i}{Y^*}$ (3.10)

The farm specific economic efficiency is defined as the ratio of minimum total production cost(C*) to actual observed total production cost (C).

$EE_i = \frac{C^*}{C}$ (3.11)

Following Farrell (1957), the AE index will be derived from equations (3.12) and (3.13) asfollows:

$AE_i = \frac{EE_i}{TE_i}$(3.12)

3.4.1.2. Determinants of Efficiency

In this study TE, AE and EE estimates were derived fromstochastic production frontier was regressed using a censored Tobit model on farm specificexplanatory variables that explain variation in efficiency across farms. The rationale behindusing a Tobit model is that there are a number of farm units for which efficiency could be 1 andthe bounded nature of efficiency between 0 and 1. That is the distribution of efficiency iscensored above from unity. Estimation with (OLS) regression of the efficiency score would leadto a biased parameter estimate since OLS regression assumes normal and homoscedastic distribution of the disturbance and the dependent variable (Greene, 2003). As the distribution ofthe estimated efficiencies is censored from above at the value 1, Tobit regression model (Tobin,1958) is specified as:

$$E_i^* = \sum_{j=0}^{n} \beta_j X_j + V \qquad (3.13)$$

$E_i = 1$ if $E_i^* \geq 1$

$E_i = E_i^*$ if $E_i^* < 1$

Where E_i is an efficiency score representing TE, AE and EE; v~N (0, σ^2) and βj are the vector parameters to be estimated; χ_i represent various farm specificvariables and E_i^* is the latent variable, with E [E_i^*/X_i] equals $X_i\beta$.

3.6. Variables Definition and Hypotheses

3.6.1. Definition of Output and Input Variables in the Production Models

i. OUTPUT: This is the endogenous variable in the production function. It is defined as theactual quantity of cumin produced and measured in quintals during the 2016/17 production year.

ii. Input: Defined as the total inputs used in the production of cumin namely: land (Ha), labor(Man-day), oxen(Number),fertilizers(Kg), seed(Kg) and chemicals(Li) used during the 2016/17 production year.

Land (LAND): This represents the total physical unit of land under cumin production in hectare.

Human labor (LABOR): Represents the total human labor employed in the production process.It was measured in man days (equal to eight hour per day).

Oxen power (OXEN): Oxen powers were measured using thetotal amount of oxen days allocated for ploughing and hoeing activities of cumin production. Itwas measured in oxen-days (one oxen-day is equivalent to eight working hours).

Fertilizer (UREA): the total amount of Urea (in Kg)used in cumin production during the 2016/17 production year.

Seed (SEED): Represents the type of cumin seed quantity used by the i^{th} household. It was includedin the production frontier function in physical quantity and measured in kg.

Chemicals (CHEM): This is a physical quantity of chemicals such as herbicides, insecticidesand pesticides applied by the sample households for protection of weed, insects and pests incumin production, respectively. It is measured in liters and its monetary value.

Given the above-specified input variables, the functional relationship between inputs and outputused in the production function can be specified as follows:

Yi = f(LAND, LABOR, OXEN, FERTILIZER, SEED, CHEMICAL; βi) +εi (3.14)

Where: Yi = Output of the i^{th}farm (qt)f(.) = appropriate functional form (e.g. Cobb-Douglas)βi = vector of unknown parameters to be estimatedεi = composed error term (εi = vi - ui)vi = a disturbance term which accounts for factors outside the control of the farmerui = non-negative random variable which captures the technical inefficiency in production

The linear functional form of Cobb-Douglas production function used for this study is given as:

$$\ln(\text{output}) = \beta_o + \beta_1\ln(\text{land}) + \beta_2\ln(\text{labor}) + \beta_3\ln(\text{oxen}) + \beta_4\ln(\text{Fertilizer}) + \beta_5\ln(\text{Seed}) + \beta_6\ln(\text{Chemical}) + vi - ui \quad (3.15)$$

3.5.2. Efficiency Factors of Cumin Production and the Working Hypotheses

Dependent Variables: The dependent variables for this study were: TE, AE andEE scores of cumin production obtain from SFPF. Independent variables are identified based on theory and previous studies on production and factors affecting efficiency of production, thefollowing variables were expected to determine efficiency differences among cuminproducers.

Age of the household head (AGE): It is a continuous variable which refers to the age of thehousehold head measured in years. It is believed that age can serve as a proxy indicator for experience. Inthis case farmers with more years of experience are expected to be more efficient. Therefore, in this study age of the household head was hypothesized to have positive effect on efficiency. However,labor productivity is also expected to decreases as the farmer gets older; younger farmers tend to be relatively moreproductive, because of the tough nature of farm operations (Ike and Inoni, 2006). In this study, the variable is captured by age squared (AGE_SQU), and it is expected to affect efficiency negatively.

Educational level of the household head (EDUCLH): This variable is measured in years offormal education and was used as a proxy variable for managerial ability. Farmers with moreyears of formal education complete tend to be more efficient. This is because education enhances ability toacquire technical knowledge, which makes them closer to the frontier. Educated farmers canthus understand, analyze, and interpret the advantage of different technologies more easily thanuneducated farmers (Gbigbi, 2011). Therefore, farmers who have more years of schooling areexpected to be more efficient.

Household size (HHSZE): A household is an important source of labor supply in rural areas. Itis expected that households with many members have better advantage of being able to use laborresources at the right time, particularly during peak cultivation periods. Therefore, householdsize could have positive effect in raising the farmer's production efficiency. However, it is important to evaluate whether relatively largehouseholds are more efficient than small ones. Following Coelli et al. (2002), it washypothesized that relatively large households in the area are expected to be more efficient than small-sized households.

Sex of the household head (SEX): This is a dummy variable that is measured as 1 if thehousehold head is male and 0, otherwise. Since female household heads are less exposed tofarming operations, they are expected to have less practical experiences in farming operation and wouldprobably use inputs less optimally than male household heads. Female-headed household areresponsible for domestic activities. Thus, they may not accomplish the farmingactivities on time and efficiently (Aynalem, 2006). Therefore, it is hypothesized that female-headedhouseholds are expected to be less efficient than their male counterparts.

Total cultivated land (TCULTLND): This refers to the total area of cultivated (own, shared orrented in) land the household managed during 2016/17 production year. According to Andreu(2008), larger farms are relatively better efficient than small size farms. Therefore, householdswith larger area of cultivated land have the capacity to use compatible technologies that couldincrease the efficiency of the household, enjoy economies of scale and relatively better efficientthan small size farms.

Credit utilization (CRDTU): This is a dummy variable that represents the use of credit for farmrelated purposes by farmers. The actual amount of credit received used 1 and 0, otherwise. Sincecredit utilized is an important source of financing the agricultural activities of smallholderfarmers (Okoye et al., 2007). It washypothesized that households who have utilized to creditsources were more efficient than others.

Frequency of extension visit (FEXTVST): Frequency of extension visits is a continuousvariable and medium for the diffusion of new technologies among farmers and hence improvesthe efficiency of farmers (Ike and Inoni, 2006). Therefore for this study, extension visit wasexpected to have a positive effect on efficiency.

Training (TRAING): This is a dummy variable that represents the access to training for farmrelated activities. If the household has got training, the variable takes a value of 1 and 0, otherwise. So, households who received training service werehypothesized to be more efficientthan those who did not receive training.

Land fragmentation (LNDFRAG): This is defined as the total number of plots that thehousehold has managed during 2016/17 production year. Increased land fragmentation leads toinefficiency by creating shortage of family labor, costing time and other resources that shouldhave been available at the same time (Fekadu and Bezabih,2009). Hence, this variable washypothesized to have a negative association between fragmentation and efficiency.

Slope (SLOPE): This was measured as a dummy variable that takes a value of 0 if a householdperceives his farm as flat slope a 1, otherwise. Slope could be one of the determinants ofefficiency. Sloppy lands are vulnerable to erosion damages and their fertility is likely to be poordue to high run-off if soil conservation measures are not taken. Getu et al. (1998) found/reporteda negative relationship between the slope of the plots and efficiency. Hence, ithypothesized thathouseholds who sow cumin on sloppy land were more efficient than those with flat slope.

Proximity (PROXTY): Defined as the distance of the farm from the house of the householdhead in walking minutes. As the plots are farther from the residence, it is more difficult tomanage the plots timely (Mekedes, 2011). Based on this argument, it washypothesized that thehousehold heads living nearby to his plots were more efficient than the one living at the farthestdistant from the plots.

Perception on agricultural policy (PAGRPOLY): It is a dummy variable that is measured as 1if they perceive the policy as favourable and 0, otherwise. Agricultural policy issues such as pricing, marketingand other public provisions are just as important as technological factors in improving overallefficiency in the smallholder subsector (Tchale, 2009). Therefore, it is hypothesized thatif the policy is perceived as favourableit is expected to affect resource use efficiency positively.

Perception on environmental hazard (PENVHZRD): This is a dummy variable and measures1 if households perceived that there is environmental hazard in the 2016/17 production year and0, otherwise. It represents factors such as climate change and weather condition can affectresource use efficiency of crop production. These factors may have a negative interaction withagricultural practices and environment (Ajibefun, 2002). Based on this fact, ithypothesizedthat the farmers living with environment hazard were less efficient than other.

Livestock holding (LIVSTK): This is the total number of livestock owned in terms of TropicalLivestock Unit (TLU). Livestock could support crop production in many ways; they can besource of cash, draft power and manure that will be used to maintain soil fertility. Therefore, in this study the effect of livestock on efficiencywashypothesized to be positive.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the results and discussion part of the study in two sub-sections. The first section presents the descriptive results and the second deals with econometric results from the stochastic frontier function and Tobit models.

4.1. Descriptive Statistics Results

Before embarking on discussing results obtained from the econometric models, it is important to briefly present demographic, farm, environmental, socio-economic and institutional characteristics, inputs used (inputs per unit of land) and crop yield (output per unit of land) which are used in SFPF of the sample farm households.

4.1.1. Demographic and Socioeconomic Characteristics of Households in North Achefer district

The average household size of the samplehouseholds was 6.81 persons per household, with standard deviation of 2.66. The result impliesthat the mean household size in the study area is relatively higher than the national averageagricultural household size which is about 5.2 persons per household (Essa, 2011). The averageage of the sample households during the survey period, was about 49.19 years with standard deviation of 11.41 (Table 4.1).

Table 4.1Household Age, Family Size and Educational level in 2016/17 production year

Variable Description	Minimum	Maximum	Mean	Std. Deviation
Age of Household Head	28	77	49.19	11.41
Household Size	3	14	6.81	2.66
Educational Level	0	12	2	3.61

Source: Own computation (2017)

Education improves themanagerial skill and the tendency to adopt new technologies. Education together with increasedexperience could guide households to better manage their farm activities. The average years of schooling of the sample household heads during the survey period was about 2 years with theminimum of zero year (illiterate) and maximum of 12 years of schooling (Table 4.1).

With regards to the sex of respondents, about 10.7% of the samplehouseholds were female headed and the remaining 89.3% were male headed. It was understoodthat female headed households in rural areas in Ethiopia face more challenges in agricultural production andmarketing compared with their male headed counterparts. This is partly due to cultural barriers and partly due to their busy schedules as theyare engaged in domestic, reproductive and communityroles (SMU, 2012).The survey result showed that thetotal number of married, divorced and widowed householdsduring the survey period was 72.1%, 8.2% and 19.7%, respectively (Table 4.2).

Table 4.2 Sex and marital status of sample households

Sex and Martial Status	Category	Number of Household	Percent
Sex	Female	13	10.7
	Male	109	89.3
Marital Status	Married	88	72.1
	Divorced	10	8.2
	Widowed	24	19.7

Source: Own Computation (2017)

4.1.2. Farm characteristics of sample households

Farmers use most of their land for crop production or grazing. The average land holding size of the farm households was about 1.83 ha. Out of which, on average,80.9% of the land (1.48 ha) is cultivated. The result implies that 59% households in the study area have relatively larger land size compared to that of the national average of farmers in Ethiopia which is 1.2 ha (Essa, 2011) and the holdings of the remaining 41% of the farmers is less than 1 ha. The average land size allocated for cumin production was approximately 0.7 hectare and its standard deviation was 0.65. The average number of cumin plots of the sample households during the survey period was 1.16 with the minimum of 1 plot and maximum of 2 plots. On average, the plots of the household take 52.13 minutes from homestead and the farm households ploughed their cumin farm 3.84 times with minimum of 3 times and maximum of 4 times (Table 4.3).This implies that the plots allocated for cumin production were lesssuitable due to water logging problems happening in medium slopped plots.Cumin is a drought tolerant crop which is less resistant in water logging situations..The survey result based on the perceptions of respondents indicated that 55% of the land allocated for cumin production had medium slope where as 18.9% and 26.2% of the allocated had flatter and steeper slope, respectively

Table 4.3 Farming characteristics and land distribution of households in North Achefer district

Variables	Minimum	Maximum	Mean	Std. Deviation
Total own farm land (ha)	0.25	3.5	1.84	1.00752
Cultivated land (ha)	0.25	3	1.49	0.8466
Total cumin land	0.25	3	0.66	0.6465
Grazing Land(ha)	0	0.5	0.2	0.1727
Homestead Land(ha)	0	0.5	0.19	0.1269
Time to Reach to Farm Plots(Minutes)	5	90	52.13	24.906
Number of Farm Plot(Number)	1	2	1.16	0.372
Ploughing Frequency(Number)	3	4	3.84	0.372

Source: Own Computation (2017)

The major crops grown in the areaincludes maize, cumin, teff and barely. On average, households allocated 0.633 ha (42.6%) of the total cultivated land for cuminproduction. Next to cumin, maize and teffwere crops that took the largest proportion of thehousehold's total cultivated land covering 0.416 and 0.293 ha, respectively(Table 4.4).The result of the survey indicated that the majority of the farm households (62.3%) used only household family labor in the production of cumin, and only in certain cases that they used family exchange and hired labour as additional source of labor supply to household labor.

Table 4.4Land allocation and productivity of various crops in north Achefer district

		Area allocated(Ha)		Productivity(Kg/Ha)
Crop Type	N	Mean	Percent	Mean
Cumin(Ha)	122	0.633	42.6%	267
Maize(Ha)	82	0.416	28%	2324.04
Barely(Ha)	52	0.143	9.6%	774.56
Teff(Ha)	62	0.293	19.8%	501.09
Total	122	1.485	100%	
F-test		*42.06****		*1533****

Source: Own Computation (2017); Significant at P<0.001

The survey result also investigated differences in the mean land allocated to different crops and the mean differences in the productivity of crops cultivated in the district. The results of the Analysis of Variance (ANOVA) revealed that there is statistically significant difference in the mean land allocated for crops cultivated in which cumin takes the lion's share followed by maize, teff and barley. In terms of mean productivity difference, there is statistically significant difference ($p<0.01$) in which farmers are more productive in maize cultivation followed by cumin, barely and teff. The mean productivity of cumin is 2.67 quintals per hectare, which is much lower than the average productivity of maize(23.24 quintals per ha) (Table 4.4).

Given a mixed farming system in the study area, livestock has considerable contribution forhousehold income and food security. Among others, oxen power is a major input in cropproduction process serving as a source of draft power. Households in the study area use oxen tocarryout different farming practices, of which ploughing was the majoractivity. However, the result indicated thatonly 9.83 % of the households own a pair of oxen and cannot independently plough their plots using their own oxen. The remaining close to 90% of the farm households cultivate their plots by lookingfor oxen exchange from others.As presented in Table 4.5, about 62% of the households own 10−20, and only about 20 % of them owned in a range between 5 and 10 TLU (Table 4.5).

Table 4.5Households livestock ownership (in TLU) during the 2016/17 production year in North Achefer district

Tropical livestock unit range	Frequency	Percentage
5−10	24	19.7
10−15	40	32.8
15−20	36	29.5
20−25	22	18

Source: Own Computation (2017)

Asset ownership can be used as a proxy indicator for wealth status of the households. More than75 % of the respondents live in iron roofed houses whereas 25% of them had thatched roof houses. Given the value of mobile phone for communication, farmers in the study area, 63% of them own mobile phone. Similarly, about 78.9 % of the households own radio, which is an opportunity to get awareness on different agricultural practices (Table 4.6).

Table 4.6 Asset ownership of sample households during 2016/17 production year

	No		Yes	
Variables	Frequency	Percent	Frequency	Percent
Corrugated Iron Roof Houses	30	24.6	92	75.4
Thatched Roof Houses	37	30.3	85	69.7
Mobile Phone Ownership	45	36.9	77	63.1
Radio Ownership	27	22.1	95	77.9
Television Ownership	111	91	11	9
Cart Ownership	118	96.7	4	3.3

Source: Own computation (2017)

4.1.3. Institutional aspects in North Achefer district

In order to give effective extension service to the households, the Amhararegional state assigned threedevelopment agents in each kebeles. The development agents are graduates from differentagricultural technical vocational education, training colleges and universities specializing in three agriculturalstreams, namely crop production, animal science and natural resource management. About78.7% of the respondents reported that they have been receiving extension services/ adviceabout cumin production. The extension workers visit households at different intervals. On average, households were being visited by extension workers10 times per year. The survey further indicated that 42 % of the total households have been receiving training on cumin production. The training covered wide range of topics such as land preparation, fertilizer applications and sowing and other management practices.

Amhara Credit and Saving Institutes (ACSI) is the only major formal source of credit in the study area. ACSI provides credit to individual households under group collateral system. Out of the total, 31 % of them had accessed credit service from the institute in the study area during the study year,while the majority of them (69%) accessed credit from informal money lenders. The survey result also indicated thatout of the total households, 30% of them had a saving culture, and deposited money in ACSI.

4.1.4. Summary statistics of variables used in the models

The production function for this study was estimated using six input variables. On average, sample households produced 2.67 qt of cumin, which is the dependent variable in the production function. The land allocated for cumin production, by sample households during the survey, ranged from 0.25 to 2 ha with an average of 0.63 ha (Table 4.7). On average, the amount of seed the households used was 10.18 kg. Like other inputs, human labor and draft power inputs were also important, given a traditional farming system in the study area.

Table 4.7Summary statistics of variables used to estimate the production function

Variables	Unit	Minimum	Maximum	Mean	Std. Deviation
Output	Qt/Ha	0.75	8	2.6721	1.82784
Land	Hectare	0.25	2	0.6332	0.46464
Labor	Man-days	17	80	36.54	17.062
Oxen	Oxen-days	1	4	2.33	0.743
Fertilizer	Kilogram	10	80	25.39	18.558
Seed	Kilogram	4	32	10.18	7.411
Chemical	Litters	0.5	4	1.275	0.9255

Source: Own computation (2017)

On average, households used 36.54adult equivalent units of labor and 2.33 oxen days for cumin production during 2016/17 production year. In the study area, households appliedonly urea for cumin production, which is estimated at 25.4kg of Urea per household. On average, about 1.3 litters of chemicals such as insecticides and pesticides were applied for cuminproduction during 2016/17 production year.

Table 4.8 Summary statistics of variables used to estimate the cost function

Variables	Unit	Mean	Std. Deviation	Percentage of total cost
Output	Qt/Ha	2.67	0.854	-
Total cost of cultivation	Birr/Ha	6172.08	-	-
Cost of land	Birr/Ha	3,247.95	2364.40	52.6
Cost of labor	Birr/Ha	1,040.16	756.18	16.9
Cost of oxen power	Birr/Ha	1039.34	756.61	16.8
Cost of fertilizer	Birr/Ha	311.80	226.98	5
Cost of seed	Birr/Ha	208.03	151.24	3.4
Cost of chemicals	Birr/Ha	324.80	236.44	5.3
		6,172.08		100

Source: Own computation (2017)

Similar to the production function, the mean and standard deviation of each variable used in the cost function along with their contribution to the total cost of cultivation are summarized and presented in Table 4.8. The average cost cultivation of Birr 6172.08 was required to produce 2.67 qt/ha of cumin. Among the various factors of production, the cost of land and labour accounted for the highest share 52.6% and 16.9%, respectively. Following the cost of land and labor, cost of oxen, chemicals, fertilizer and seed takes 16.8%, 5.3%, 5 and 3.4%, respectively out of total cost of cultivation. Among other inputs, cost of seed and fertilizer took the smallest 5% and 3.4%, respectively shares out of the total cost of cumin cultivation.

4.2. Econometric Results

The stochastic production frontier wasestimated following the maximum likelihood estimation procedure. In this study the dependent variable of themodel was cuminoutput (Qt/ha) produced during 2016/17 production year and the inputvariables used in the analysis were: land area under cumin (ha) cultivation, labor (man-days), oxen (oxen-days), fertilizer (Kg), seed (Kg) and chemicals (litters).Before running the econometric model, it was tested against econometric problems.In this study, the value of VIF for all the variables entered into the model was below 10, which indicate the absence of severe multicollinearity problem amongthe explanatory variables.Moreover, Breusch-Pagan test was also used to detect the presence of hetroskedasticity. The ML(Maximum Likelihood) estimators of Tobit regression model are inconsistent if there isheteroskedasticity problem (Greene, 2003). Therefore, the test result indicated that there was noproblem of hetroskedasticity in the model.

4.2.1. Estimation Results of the Production and Cost Functions

The maximum likelihood estimation results of the parameters using the SFPF equation specified and presented in equation (3.3) were obtainedusing STATA 12.0 computer program. The value of σ^2 for the frontier of cumin output was 0.11 which was significantly different from zero and significant at 1% level of significance. The significant value of the sigma square indicates the goodness of fit and correctness of the specified assumption of the composite error terms distribution.The results of the model showed that two of the inputvariables in the production function: i.elabor and fertilizer had a positive andsignificant effect on the level of cumin productivity (Table 4.9). Hence, the increase in these inputswould increaseproductivity of cumin significantly as expected.The coefficients of the production function are interpreted as elasticity. The highest coefficient ofoutput to fertilizer (0.24) indicated that fertilizeris the main determinant of cumin production in thestudy area.Cumin production is also relatively sensitive to the application of different units of labor. If there is a one percent increase inthe amount of fertilizer, and number of laborwould increase cuminproduction by 24percent and 22percent, respectively. In other words the increase ofthese inputs will increase output of cumin production significantly at 95, 99 level of confidence interval respectively (Table 4.9).

Table 4.9. Estimation of the Cobb-Douglas Frontier Production Function

Variables	Parameter	Coefficients	Std. Error	P-value
Constant	β0	0.67	0.35 0.000	
ln(land)	β1	-0.34***	0.10	0.002
ln(labor)	β2	0.22***	0.11	0.006
ln(fertilizer)	B3	0.24**	0.76	0.020
ln(seed)	B4	-0.38***	0.12	0.001
ln(chemical)	B5	-0.43	0.71	0.485
Sigma square (σ^2)		0.11	0.15	
Gamma (γ)		0.97	0.38	
Log likelihood function		0.13		

Source: Own computation (2017)

*** Significant at $p<0.01$ and **Significant at $p<0.05$

The ratio of the standard error of u (σu) to standard error v (σv), known as lambda (λ), was 5.67.Based on the above table (4.9), gamma (γ) which measures the effect of technical inefficiency in the variationof observed output can be derived ($\gamma = \lambda^2/(1+\lambda^2)$). The estimated value of gamma was 0.97which indicates that 97% of total variation in cumin farm output was due to technicalinefficiency.The returns to scale analysis can serve as a measure of total factor productivity (Gbigbi, 2011)and the coefficients were calculated to be -0.69, indicating decreasing returns to scale (Table 4.10).

Negative return to scale is an extreme form of decreasing returns to scale, in which increasing all inputs in proportion actually causes output to fall. This implies that there was limitation for cumin producer to change to the production of other crops because they are in the stage III of production surface where resource use and production is believed to be inefficient. In other words, a one percent increase in all inputs proportionally would decrease the total production by -0.69.

Table 4.10. Elasticity and Returns to Scale of the Parameters in the Production Function

Variables	Elasticity of Production
ln(land)	-0.34
ln(labor)	0.22
ln(fertilizer)	0.24
ln(seed)	-0.38
ln(chemical)	-0.43
Return to scale	-0.69

Source: Own competition (2017)

Inadequate farm level price data coupled with little or no input price variation across farmers ofEthiopia precludes any econometric estimation of a cost or profit frontier function. Therefore, theuse of self-dual production function allows the cost frontier function to be derived and used toestimate economic efficiency in situations where producers face the same input prices was givenas follows:

$\ln C_{cumin}$=1.34 - 0.18W_{1i}-0.11W_{2i}+0.51W_{3i}-0.22W_{4i}-0.26W_{5i}-ln Y_i^*

Where $C_{Cumin}$is the minimum cost of cumin production; $W_{1i}$is the average rent value of land per ha;W_{2i} is the average wage per day; $W_{3i}$is the average price of fertilizer per kg; W_{4i} is the average price of seed perkg; $W_{5i}$is the average price of chemicals per litters and ln $Y_i^*$is the total amount of cumin produced inqt quantities adjusted for statistical noise.

4.2.2. Hypotheses testing

Before discussing about parameter estimates of production frontier function and the inefficiencyeffects, it is advisable to run the several hypotheses tests in order to choose an appropriate modelfor further analysis and interpretation. One attractive feature of SFPF method is that it makes it possible to test various hypotheses using maximum likelihood ratio, which were not possible in non-parametric models. Accordingly, two hypotheses tests wereconducted; one for the existence of inefficiency and other for variables that explain thedifference in efficiency. The first test examines where the average production function best fitsthe data so as to verify whether there exists considerable inefficiency among households in theproduction of cumin in the study area. The second hypotheses tests whether all coefficients of theinefficiency effect model are simultaneously equal to zero (i.e. H_o: $\delta_0 = \delta_1 = \delta_2 = ... = \delta_{15} = 0$). Inother words, it was to check whether the explanatory variables in the inefficiency effect modelcontribute significantly to the technical inefficiency variations among cumin producinghouseholds. Generally, tests of hypotheses for the parameters of the frontier model wereconducted using the generalized likelihood ratio statistics, λ , which can be defined as:

$\lambda = - [\log L\ (H_o) - (\log L(H_A))]$ (4.2)

Where, $L(H_o)$and $L(H_A)$are the values of the log-likelihood function under the null and alternative hypotheses, H_o and H_A, respectively.

Table 4.11. Generalized Likelihood Ratio tests of Hypotheses for the Parameters of the SFPF

Null hypothesis	Λ	Critical value (x^2,0.95)	Decision
$H_o=\gamma=0$	3.89	1.72	Reject H_o
$H_o=\delta_1= \delta_2=....= \delta_{15}$	34.62	6.98	Reject H_o

Source: Own competition (2017)

The likelihood test static obtained from the log likelihood functions of both the average responsefunction (OLS specification) and stochastic production function were found to be greater thancritical value (χ^2). This implies that traditional average production function does not adequatelyrepresent the data. Therefore, the null hypotheses that the average response function is anadequate representation of the data was rejected and the alternative hypotheses that stated there exist considerable inefficiency among cumin producing households were accepted.Similarly, $H_a$was also tested in the same way by calculating the likelihood ratio value using the value of the log likelihood function under the stochastic frontier model (H_0) and the full frontier model with variables that are supposed to determine inefficiency level of each household (H_a).The value obtained was again higher than critical χ^2 value at the degree of freedom equal to thenumber of restrictions. The result suggested that the null hypothesis is rejected and the alternative hypotheses that the explanatory variables associated with inefficiency effect model are simultaneously different from zero. It implies, these variables simultaneously explain thedifferences in efficiency among cumin producing households.

4.2.3. Efficiency Scores

The result of the efficiency scores indicates that there were wide ranges of differences in TE,AE and EE among cumin producing households. The mean TE, AE and EE were found to be close to

89%, 44% and 38%, respectively. Themodel output presented in Table 4.12 indicates that farm households in North Achefer district are relatively good in TE than AE and EE (Table 4.12).

Table 4.12. Summary Statistics of Efficiency Measures

Type of Efficiency	Min	Max	Mean	Std. Deviation
TE	57.76	96.36	88.95	0.0667
AE	21.79	85.34	43.27	0.1220
EE	0.00	77.74	38.15	0.117

Source: Own computation (2017)

On average, if households in the study area operated at full efficiency level, they would have increased their output by 11.05% using the existing resources and level of technology. In other words, it implies that, on average, sample households North Achefer district candecrease their inputs (land, labor, oxen, Urea, DAP, seed and chemicals) by 11.05% to get theoutput they are currently getting (Table 4.12).The mean score of AE was 43.27% (Table 4.12). The result indicates that on average households in the study area could increase cumin output by 56.73% if they use the rightinputs and produce the right output relative to the input costs and output price. The results indicated that households can increase cumin production by 11% without increasing inputs if they were technically efficient, they can reduce the current cost of inputs by 57% by adopting a cost minimization strategy, and there is a room to improve EE by 62% when resources are used efficiently.

The level of TE among the cumin producing households is presented in Table 4.13. The households had ranges of 57% to 97% with standard deviation of 0.1. The result showed thatthe majority of the sample households have TE score of 81% to 90%. But,about 29 % of the households have TE levels limited to the range of 51% to 80%. The farmhouseholds in this group have a room to enhance their cumin production at least by 20%. Out of the total households, 26.6% of them have TE of greater than90%. This implies that around 73.4 % of them can increase their production by, atleast, 10%.The results of the AE distribution scores indicate that the largest efficiency group ofcumin producers (49.2%) operated between 41% and 50%. Households in this group can save atleast 50% of their current cost of inputs by behaving in a cost minimizing way. No farm household had an AE score that ranged between 90% and 100%, showing that almost cumin producing households (100%) can at least save 10% of their current input cost by reallocation of resources in cost minimizing way (Table 4.13).

Table 4.13. Frequency Distribution of TE, AE and EE of Households in North Achefer district

Efficiency	TE		AE		EE	
ranges	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
<10	0	0	0	0	1	0.82
10−20	0	0	0	0	0	0
20−30	0	0	20	16.4	24	19.67
30−40	0	0	22	18	52	42.62
40−50	0	0	60	49.2	35	28.69
50−60	4	3.28	11	9.02	3	2.46
60−70	0	0	3	2.46	4	3.28
70−80	4	3.28	3	2.46	3	2.46
80−90	49	40.16	3	2.46	0	0
90−100	65	53.28	0	0	0	0

Source: Own computation (2017)

The distribution of EE scores implies that about 40 % of cumin producing farmers were performing belowaverage efficiency level. About 43 % of cumin producers in the study area were operatingbetween 31% and 40% level of efficiency. Households in this group can save at least 60% of their current cost ofinputs by behaving in a cost minimizing way. The low level of EE was the total effect of bothtechnical and allocative inefficiencies. This also indicates the existence of substantial economicinefficiency in the production of cumin during 2016/17 production year (Table 4.13).

4.2.4. Determinants of efficiency in cumin production among sample households

The major interest behind measuring TE, AE and EE level is to know what factors determine the efficiency level of individual farm households, and to come up with development and policy recommendations that improve their efficiency. The TE, AE and EE scores derived from the model were regressed on socioeconomic, demographic, farm, institutional and environmental variables that explain variations inefficiency across farm households using the Tobit regression model. The estimation of the Tobit regression model showed that ageof household's head, sex of household, slope of plot, and agricultural policy were found to be statistically significant in explaining the variation in the level of technical efficiency whereas three variables such as educational level, frequency of extension visit, and livestock holdingsignificantly explained the variation inallocative efficiency of cumin producers. Moreover, the result of the model also revealed that age of the household head, education, amount of credit borrowed and agricultural policy were significant in explaining the variation in economic efficiency of cumin producers in the study area. Detail discussionsof the results from the Tobit model are presented below.

Table 4.14. Determinants of efficiency in cumin production among sample households

	TE		AE		EE	
Variables	ME ($d_y/d_{x)}$)	Std. Error	ME ($d_y/d_{x)}$)	Std. Error	ME ($d_y/d_{x)}$)	Std. Error
Constant	1.045131***	0.0625883	0.4404468**	0.1116001	0.4713633***	0.1012195
Age HH	0.0001093**	0.0006137	0.0013687	0.0010943	0.0014929**	0.0009926
AGE_SQU	-0.001700	0.0008	0.0005	0.0009	0.00011	0.00010
Education	0.0010871	0.0022126	0.0012876**	0.0039461	0.0021735***	0.0035825
HHSZE	0.0032596	0.0025899	0.0266145	0.0345071	0.0065819	0.0041931
Sex HH	-0.0195972*	0.0193443	0.0266145	0.0345071	0.0168024	0.0313037
TCULTLND	-0.0013963	0.0075801	-0.0152566	0.0135213	-0.0189969	0.0122701
CRDTU	0.0187098	0.0130625	0.0402105	0.0232964	0.0246544*	0.0211155
FEXTVST	0.0097806	0.0148497	0.0248365***	0.0265058	0.01611	0.0240049
TRAINING	0.022699	0.0121366	0.0480064	0.0216521	0.0333223	0.0196301
LNDFRAG	-0.0159159	0.0149022	-0.0461149	0.0265778	-0.0566732	0.0241175
SLOPE	0.0024332***	0.0090075	0.0456655	0.0160832	-0.0454947	0.014598
PROXITY	-0.0005851	0.0002495	0.0000833	0.0004446	-0.0002488	0.0004032
PAGRPOLY	0.0141363**	0.0136763	0.0254833	0.0243724	0.0271416***	0.0221095
PENVHZRD	-0.0259632	0.0227058	0.0057038	0.0407869	0.0126982	0.0369357
LIVSTK	0.0123251	0.006119	0.0032808*	0.0109089	-0.00627	0.009902
LOG. L	150.69967		91.032617		102.75025	

Source: Own competition (2017)

*** Significant at p<0.01; **Significant at p<0.05; ***Significant at p<0.1ME=Marginal Effect

Age of the household head: The estimated coefficient of age for TE is positive and significant at 5% level of significance. This implies that age contributed positively to TE, the result is similar to the finding of Arega and Rashid (2005), Dawang et.al (2011) Gibgibi (2011) and Kifle (2014) which may be because of the farming experiences that have been accumulated over years. As age increases by one year, cumin producers become skilful and farmers may develop theinterest of using new methods ofproduction by one percent increases. The estimated coefficient of age for EE requires greater knowledgeand skill that gathered over time, this increases the capacity of households for produced optimaloutput and optimal allocation of resources and technology.

Education: Education had significant effect on AE with expected sign. It is positive and significant at 1% level of significance. The significant effect of education on AE confirms the importance of education in increasing the efficiency of cumin production. The result indicates that, AE require better knowledge and managerial skill than TE and EE. In other words, educated households have relatively better capacity for optimal allocation of inputs. In line with this study, research done by Aynalem (2006) in North Ethiopia, Keinde and Awoyemi (2009) and Ogundari and Ojo (2007) both in Nigeria and Kifle (2014) have also found education to influence AE positively andsignificantly.

Sex of household head: Sex of household head was found to have negative and significant influence on TE at 1% level of significance, which is in line with the hypotheses made. The implication is those female households headed are the one who were responsible for many household domestic activities such as collecting of fire wood from the field, fetching water from the far distant rivers, childrearing and household management obligations and also probably use inputs fewer than male household heads.This result is consistent with Aynalem (2006), Isah *et al*. (2013) and Kifle (2014).

Livestock holding: The result indicated that there was a positive sign and significant impact of livestock ownership on AE at 10%, as in the case of Aynalem (2006), Wondimu (2010), Solomon (2012) and Kifle (2014) confirms the considerable contribution of livestock in reducing the current cost of inputs in cumin production. Given the importance of livestock in the spice production system as source of draft power, food, income, for inputs purchase and organic fertilizers the model result seems logical to affect AE positively as expected.

Slope: The result indicated that there was a positive sign and significant impact of slope on TE at 1% level, and the considerable contribution of slope in increasing the current productivity cumin. Sloppy lands do not capture water these imply fertility is likely to be highdue to low capture of water. The result depicts positive relationship between the slope of the plots and efficiency. Hence, it hypothesized that households who sow cumin on sloppy land were more efficient than those with flat slope.

Credit utilized: The result also indicated that credit utilized had a positive sign and statistically significant effect on EE level at 1%, which suggests, that on average households with credit utilized tend to exhibit higher levels of efficiency. Credit utilized permits a household to enhance efficiency by removing money constraints which may affect their ability to apply inputs, implements and farm management decisions on time. Hence use of credit reduces the problem of financial constraints, ensures timely supply and use of inputs and results in increased economic efficiency of the households in the study area. This finding is consistent with the result by Hasan (2006), Gbigbi (2011) and Kifle (2014).

Frequency of extension visits: Extension visit was the number of times that the households contact with extension agents. Farm households who received regular extension visits by extension workers appear to be more allocative efficient than their counterparts. The coefficient for the access to extension visit had statistically significant and positive relationship with AE at 1% level. The positive estimated coefficient for contact with extension workers imply that efficiency increases with the number of visits made to the farm household by extension workers.

Perception on agricultural policy: Households were asked about their perception with regards to the existing agricultural policies like pricing, marketing, natural resource conservation and one to five team formulations they have benefited from government support programs. The result showed that the variable had positive sign and significant effect on TE, AE and EE at 1% level as expected. This implied that households who feel benefits from the government policies have the score of TE, AE and EE higher than those who have not perceived benefits from agricultural policies under taken by the government. The result is consistent with Khai and Yabe (2011) and Kifle (2014) whofound positive relationship between agricultural policy and efficiency.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study was conducted to estimate TE, AE and EE and to identifyfactors affecting efficiency among cumin producer households in North Achefer District, Amhara National Regional State, Ethiopia. The Ethiopian government launched a new extension program which is expected to bring significant improvements in the production and productivity of Ethiopian agriculture by using technologies (Kifle, 2014). Theagricultural outputs could be increased either through introduction of modern technologies or byimproving efficiency of inputs. This implies the need for integration of modern technologies withimproved level of efficiency. The estimated stochastic production frontier model indicated that humanlabor and amounts of fertilizer were significant determinants ofefficiency level. The positive coefficient of these parameters indicated that increased use ofthese inputs would increase the efficiency level to greater extent.Accordingly, the analysis of the efficiency of cumin production provided opportunity to enhancethe level of TE, AE and EE of cumin producing households. The SFPF and self-dual cost function indicated that the average TE,AE and EE value of cumin producing farmerswere 88.95%, 43.27% and 38.15%, respectively. Theresults indicated that households can increase cumin production by 11% without increasinginputs if they were technically efficient, they can reduce the current cost of inputsby 57% by adopting a costminimization strategy, and there is a room to improve EE by 62% when resources are usedefficiently.

To solace different stakeholders to enhance the current level of efficiency in cumin production and to identify factors affecting the efficiency of cumin production, Tobit model was employed. Accordingly, the results of the Tobit regression model revealed that age of household heads, slope and perceived favourable agricultural policy had positive and significant effect while sex of household heads had negative and significant effect on TE as expected. AE is the ability to use least cost combination of inputs to produce a given output was affected by education level, frequency of extension visit, perceived favourable agricultural policy and livestock holding had positive and significant effect on as expected. Finally, age of household heads, education, credit utilized and perceived favourableagricultural policy had positive and significant effect on EE as expected.

Farmland is a scarce resource, and unless used efficiently, it can’t support an ever increasing population. Efficiency studies ensure that scarce resources are used to generate the maximum physical product from a given combination of inputs (technical efficiency) and producers generate the most economical value out of a given combination of inputs (economic efficiency). When farmlands are used inefficiently, local as well as national food security objectives can’t be addressed. From the results of this study, which is summarized above, cumin is a very important cash crop for north Achefer farmers. But, production and productivity is found to be inefficient. This will have implications in terms of affecting the incomes and local level food security of the district. Therefore, it can be concluded that unless the correlates of inefficiency of cumin production are addressed by those concerned institutions, then incomes and their food security status will be affected.

5.2. Recommendations

Therefore, based on the findings of this study, policy implications are made to enhance resource use efficiency and increase cumin efficiency in the study area.

- Education of household heads affected technical efficiencyof cumin producers. Hence, government should designappropriate policy to provide formal and non-formal education opportunities tothe rural populationso that households can use the available inputs more efficiently under the existingtechnology.
- According to the results from this study, female head households were found to be less technically efficient than male head households. While still further studies are needed to ascertain as to why female headed households are less efficient in cumin production, gender mainstreaming is still important to address women farmers’ production related challenges.
- This study provided evidence on the role of credit utilization in improving allocative efficiency of cumin producers. Therefore, efforts towards establishing and strengthening of micro-finance institutions are required.
- Policies and strategies that improve extension services could help raise the efficiency of cumin production. Hence, the number of visits by extension agents should be increased

and appropriate training and advisory services on various topics that improve their efficiency should be provided to the cumin producers.

- Given the mixed farming system in the study area, farmers with large number of livestock were relatively better in the allocative efficiency. Hence, there is a need to design appropriate policy and strategies for improving livestock production systems by solving the shortage of feed and providing various technical and advisory support services, which in turn would enhance the efficiency of cumin production.
- Finally, the existing level of inefficiency in cumin production is high and this calls for betterattention of policy makers, and development practitioners in tackling the sources of these inefficienciestoimprove the welfare of cumin producing farmers.

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APPENDIX

Appendix 1

1. General Information on Household Head

A. Household head Information

1. Sex of the Household head   0.Female   1.Male

2. Age of Household head   ____________

3. What is the educational status of the household head?__________________________

4. Marital status: 1. Single 2.Married3.Divorced 4.Widow 5.Other, specify.............

5. Household Size: ______________________

B. Farmer Assets

1. General asset ownership of the household and their value

Description	Do you have(1.yes 2.No)	Number	Current value	Remark
Corrupted Iron House				
Grass Roofed House				
Mobile				
Radio				
Television				
Cart				

D. Farm implements

1. Farm implements ownership in number and value

Description	Number	Unit price	Total price
Ox-plough			
Hoe			
Sickle			
Pick Axe			

2. Input and Output Information's

1. Total Area of land ………… (ha)

2. Land covered by cumin…………………..(ha)

3. Cultivated land………….. (ha)

4. Grazing land……………..... (ha)

5. Homestead land…………..... (ha)   6. Other land, specify ……… ……………….(ha)

2. Cropping pattern and major spices grown in the area during 2015/16 production season

Name of crops	Allocated land(ha)	Production(Qt)	Type of seed used		Did you use fertilizer? 1. Yes 2. No
			Local	Improved	
White Cumin					
Maize					
Teff					
Barely					
Other					

Give major reasons why you produce cumin? 1. High yield 2. Required lower labor 3.High grain price 4. Stover (residue) yield 5. Pest and disease tolerance 6. Other, specify.................

Have you involved in share cropping and land rent for cumin production? 1. Yes 2. No

How many plots did you use to produce cumin in the year 2015/2016 production season? .....

Do you use inputs in cumin field? 1. Yes 2. No

If yes, fill the following Table?

Types of Inputs	Size (ha)	Amount used in kg (lit)	Cost per unit	Total cost	Distance from home
Cumin seed					
Plot 1					
2					
Inorganic fertilizer					
Urea					
Plot 1					
2					
Pesticide					

8. If not used organic fertilizers, why? 1. It is bulky to transport 2. Lack of awareness 3. I don't have animals to prepare it 4. Other, specify..

9. Do you have problem in supply and marketing of Inorganic fertilizers? 1. Yes 2.No

10. If yes, what are the major problems regards supply and marketing of inorganic fertilizers? 1. Not supplied timely 2. Shortages of fertilizers supply 3. The price is high 4. Source is far from home 5. Other, specify............................

11. Is there any labor constraint? 1. Yes 2.No

12. If yes, how you get additional labor required? 1. Family labor 2. Family and hiredlabor3. Family and exchange labor

13. How much did you pay for hired labor per day (8hrs)...............

14. Amount of human and oxen labor allocated in the process of cumin production, if different between plots ask each

Plots	Oxen days		Total labor use in persons days/Man days																Cost to thresher
			Land Preparation			Planting			Weed Control				Harvesting			Threshing			
	Plowing Frequency	Total Plowing days	Male	Female	Children	Male	Female	Children	Weed Freq	Male	Female	Children	Male	Female	Children	Male	Female	Children	
1																			
2																			

15. Amount of cumin produced in 2015/16 production year?

Type of land	Produced	Soil type	Soil status	Soil slope	Plot ownership	Previous field
Plot 1						
Plot 2						

16. Do you have a saving behavior? 1. Yes 2. No

17. How much did you save in 2015/2016 production year?......................

18. Where do you saved? 1. Home 2. Micro-finance institutions 3.Banks 4. Other, specify...........

19. Is there any interest rate associated with the money you saved? 1. Yes 2. No

20. If yes, how much is the interest rate (%)?.....................

21. Source of oxen for 2015/16 production year 1 own 2. Rented 3. Exchange labor 4. Shared

22. If any oxen rented amount paid per day..........

23. If there is exchange ox to labor, what is the ratio of ox to labor? 1. Equal 2. One to two 3. One to three 4. One to four

3. Market information

1. Do you have market? 1. Yes 2. No

2. How far is the market from your home? 1. 0-5 km 2. 6-11km 3. 12-16km 4. Above 17 km

3.Do you buy and sell annual crops in 2015/16 production year? 1. Yes 2. No

2. If yes, answer the following question

Crops	Amount Produced (Qt)	Amount sold (Qt)	Mode of transportation(□*)	Distance from home	Per unit cost	Total cost
Cumin						
Maize						
Teff						
Barely						

A* 1.Human labor 2.Car 3.Cart 4.Horse 5. Donkey 6. Others/ Specify............................

3. For whom did you sell your last season cumin product? 1. Wholesalers 2. Retailers 3.Consumers 4.Cooperatives 5.Farmers 6. Collectors 7.Middleman

4. Do you have enough market demand for your cumin production? 1. Yes 2. No

5. If no, what are the major reasons? 1. Excess supply during harvesting time 2. Few trader

6. Do you believe that the current market price for cumin is fair (good)? 1. Yes 2. No

7. If no, what are the major reasons? 1. Low price (below average) 2. Fluctuation 3.Chief weight

8. How is the price for your cumin product decided in the market? 1. Farmer 2. Traders 3.Both

9. What is the selling price 1 kg cumin at harvesting time........and slack period.......... 2015/16?

4. Others Efficiency Factors

1. Is there any environmental hazards occurred in 2015/16 production year? 1.Yes 2. No

2. If yes, tell the types of environmental hazard 1. Climate change 2. Weather condition

3. Do you have any source of income other than farming? 1. Yes 2. No

4. Tell number, purpose and current value of animal if you have?

Class of livestock	Number	Purpose□*	Value	Remarks
Cow				
Ox				
Sheep				
Goat				
Donkey				
Horse				
Poultry				

5. Is there any agricultural policy in your locality? 1. Yes 2.No

6. If yes, tell kinds of agriculture policies you know? 1. Soil conservation 3. One to five team formation4. Pricing 5. Marketing

7. Is there any awareness about benefit from these policies? 1. Yes 2. No

8. If yes, are perceive favorable from these existing agricultural policies? 1. Yes 2. No

9. Did you use credit in 2015/16 production season? 1. Yes 2. No

10. If yes, fill the following table (first start from formal credit, if any)

Type of credit	Kind of credit	Source of credit	Purpose	Amount	Interest (%)

A*1.Formal 2.Informal **B***1 Short term 2.medium term 3. long term **C***1.Commecial Bank 2. AmharaCredit and saving institution 3.Relatives 4.Friends 5.Money lender **D***1. Purchase inputs 2.school fee 3.Medical 4.Primary basic need 5.Buy livestock 6. Petty trade

11. What are the collateral (security) requested for the credit from the formal credit?1. Animals 2.Land 3. Friends or relatives guarantee 4. With no guarantee 5. Other, specify...........................

12. What are the collateral (security) requested for the informal lenders? 1. Animals 2. Land 3. Friends or relatives guarantee 4. With no guarantee 5. Other, specify..............................

13. Of the total amount you borrowed in production year 2015/2016, how much proportions have you repaid? 1. Full 2. Half 3.More than half 4. Less than half

14. Is there any problems regards to credit? 1. Yes 2.No

15. If yes, what are there? 1. Collateral problem 2. High interest rate 3. Time of repayment

16. Do you get agricultural extension support about the production of cumin? 1. Yes 2. No

17. If yes, what are there? 1. Input access 2.Training 3. Market Access 4. Other…………

18. Did you contact agricultural extension agency with you? 1. Yes 2. No

19. If yes, how many contact with (DA) per year or in 2015/16 year? ....

20. Have you ever received any training in out of your locality? 1. Yes 2. No

21. If yes, what type of training? 1.Soilconservation 2. Cumin production system

22. Sources of training1.Research Centers2.NGO(s)3. Private investor(s) 4. District office

Appendix 2 Economic efficiency score of the sample farmers (SPF)

F.C	EE	F.C	EE	F.C	EE	F.C	EE	F.C	EE
1	0.498638	26	0.777413	51	0.471213	76	0.441558	101	0.264085
2	0.303259	27	0.272135	52	0.391517	77	0.241378	102	0.235992
3	0.414471	28	0.385452	53	0.409171	78	0.675004	103	0.374518
4	0.443275	29	0.394662	54	0.264085	79	0.398134	104	0.388123
5	0.292055	30	0.325356	55	0.235992	80	0.38255	105	0.406403
6	0.457486	31	0.399945	56	0.374518	81	0.40014	106	0.320352
7	0.297578	32	0.382139	57	0.388123	82	0.436025	107	0.777413
8	0.419894	33	0.225685	58	0.406403	83	0.405427	108	0.272135
9	0.436036	34	0.39613	59	0.320352	84	0.30261	109	0.385452
10	0.330919	35	0.244041	60	0.777413	85	0.61175	110	0.394662
11	0.270082	36	0.316535	61	0.272135	86	0.38663	111	0.325356
12	0.374489	37	0.519029	62	0.385452	87	0.364674	112	0.399945
13	0.436077	38	0.390847	63	0.394662	88	0.39909	113	0.382139
14	0.201162	39	0.318042	64	0.325356	89	0.336261	114	0.225685
15	0.261135	40	0.414225	65	0.399945	90	0.277819	115	0.39613
16	0.608772	41	0.330919	66	0.382139	91	0.224567	116	0.244041
17	0.420411	42	0.270082	67	0.225685	92	0.492732	117	0.316535
18	0.404972	43	0.374489	68	0.39613	93	0.459797	118	0.519029
19	0.428796	44	0.436077	69	0.244041	94	0.428188	119	0.390847
20	0.410453	45	0.201162	70	0.316535	95	0.284231	120	0.318042
21	0.384064	46	0.261135	71	0.519029	96	0.305172	121	0.414225
22	0.387228	47	0.608772	72	0.390847	97	0.355246	122	0.436382
23	0.406347	48	0.420411	73	0.318042	98	0.449073		
24	0.337088	49	0.404972	74	0.414225	99	0.466709		
25	0.378521	50	0.428796	75	0.436382	100	0.471751		

Source: Own computation (2017)

Appendix 3 Technical Efficiency score of the sample farmers (SPF)

F.C	TE	F.C	TE	F.C	TE	F.C	TE	F.C	TE
1	0.91488602	26	0.9109176	51	0.9302807	76	0.890769	101	0.924804
2	0.85705493	27	0.9425045	52	0.9271138	77	0.889614	102	0.882223
3	0.87682695	28	0.9635767	53	0.8731082	78	0.863313	103	0.923172
4	0.90458829	29	0.9205715	54	0.5775923	79	0.919425	104	0.890769
5	0.87360846	30	0.9236830	55	0.8389394	80	0.895890	105	0.889614
6	0.91974798	31	0.9446321	56	0.7931846	81	0.930280	106	0.863313
7	0.89910671	32	0.9163587	57	0.8640745	82	0.927113	107	0.919425
8	0.89751056	33	0.9148860	58	0.9109176	83	0.873108	108	0.895890
9	0.9149114	34	0.9289491	59	0.9425045	84	0.577592	109	0.930280
10	0.90750845	35	0.8768269	60	0.9635767	85	0.838939	110	0.927113
11	0.92480484	36	0.9045882	61	0.9205715	86	0.793184	111	0.873108
12	0.88222381	37	0.9444577	62	0.9236830	87	0.864074	112	0.577592
13	0.92317219	38	0.9197479	63	0.9148860	88	0.910917	113	0.838939
14	0.89076981	39	0.8991067	64	0.8570549	89	0.942504	114	0.793184
15	0.88961446	40	0.8975105	65	0.8768269	90	0.963576	115	0.864074
16	0.86331378	41	0.9149114	66	0.9045882	91	0.914886	116	0.910917
17	0.91942537	42	0.9075084	67	0.8736084	92	0.857054	117	0.942504
18	0.92296263	43	0.9248048	68	0.9197479	93	0.876827	118	0.963576
19	0.9302807	44	0.8822238	69	0.8991067	94	0.904588	119	0.920571
20	0.92711387	45	0.9231721	70	0.8975105	95	0.873608	120	0.923683
21	0.87310826	46	0.8907698	71	0.9149114	96	0.919748	121	0.944632
22	0.5775923	47	0.8896144	72	0.9075084	97	0.899106	122	0.916358
23	0.83893949	48	0.8633137	73	0.9248048	98	0.897510		
24	0.79318468	49	0.9194253	74	0.8822238	99	0.914911		
25	0.86407454	50	0.8958907	75	0.9231722	100	0.907508		

Source: Own computation (2017)

Appendix 4Allocative Efficiency score of the sample farmers (SPF)

F.C	AE	F.C	AE	F.C	AE	F.C	AE	F.C	AE
1	0.545027	26	0.853439	51	0.506528	76	0.495703	0.285557	0.285557
2	0.353838	27	0.288736	52	0.422297	77	0.271328	0.267496	0.267496
3	0.472694	28	0.400022	53	0.468637	78	0.781875	0.405686	0.405686
4	0.49003	29	0.428714	54	0.457217	79	0.433024	0.435716	0.435716
5	0.334309	30	0.352238	55	0.281298	80	0.427005	0.456830	0.456830
6	0.497404	31	0.423387	56	0.47217	81	0.430128	0.371072	0.371072
7	0.330971	32	0.417019	57	0.449178	82	0.470303	0.845542	0.845542
8	0.467843	33	0.246681	58	0.446147	83	0.464349	0.303759	0.303759
9	0.476588	34	0.426428	59	0.339894	84	0.523916	0.414339	0.414339
10	0.364646	35	0.278323	60	0.806799	85	0.729194	0.425688	0.425688
11	0.292042	36	0.349922	61	0.295615	86	0.487440	0.372641	0.372641
12	0.424483	37	0.549552	62	0.417299	87	0.422040	0.692434	0.692434
13	0.472368	38	0.42495	63	0.431378	88	0.438118	0.455502	0.455502
14	0.225829	39	0.353731	64	0.379621	89	0.356773	0.284530	0.284530
15	0.293537	40	0.461527	65	0.456128	90	0.288320	0.458444	0.458444
16	0.705157	41	0.361695	66	0.422445	91	0.245459	0.267906	0.267906
17	0.457254	42	0.297608	67	0.258337	92	0.574913	0.335844	0.335844
18	0.438774	43	0.404938	68	0.430694	93	0.524387	0.538648	0.538648
19	0.460932	44	0.494293	69	0.271426	94	0.473351	0.424569	0.424569
20	0.442721	45	0.217903	70	0.352681	95	0.325352	0.344319	0.344319
21	0.439881	46	0.293157	71	0.5673	96	0.331799	0.438504	0.438504
22	0.670418	47	0.68431	72	0.430681	97	0.395109	0.476213	0.476213
23	0.484358	48	0.486974	73	0.3439017	98	0.500354		
24	0.42498	49	0.440462	74	0.4695237	99	0.510113		
25	0.438065	50	0.478625	75	0.4726984	100	0.519831		

Source: Own computation (2017)

Appendix 5.VIF for the variables entered into stochasticfrontier model

Variable	VIF	1/VIF
LNLAND	7.62	0.1312
LNSEED	3.46	0.2890
LNFERTILIZER	2.08	0.48.07
LNLABOR	1.29	0.7751
LNCHEML	2.05	0.4878
Mean VIF	3.3	

Appendix 6. Conversion factors used to estimate Tropical Livestock Unit equivalents

Animal category	TLU
Calf	0.25
Weaned Calf	0.34
Donkey (Young)	0.35
Donkey (adult)	0.70
Camel	1.25
Heifer	0.75
Sheep and Goat (adult)	0.13
Caw and Ox	1.00
Sheep and Goat young	0.06
Horse	1.10
Chicken	0.013

Source: Storck et al. (1991)

Appendix7. Conversion factor of man equivalent and adult equivalent

Age category(Years)	Man-equivalent		Adult-equivalent	
	Male	Female	Male	Female
<10	0	0	0.6	0.6
11-13	0.2	0.2	0.9	0.8
14-16	0.5	0.4	1	0.75
17-50	1	0.8	1	0.75
>50	0.7	0.5	1	0.7

Source: Storck, *et al* (1991)