DETERMINANTS OF TECHNICAL EFFICIENCY OF MAIZE PRODUCTION OF SMALLHOLDER FARMERS; THE CASE OF FOGERA DISTRICT, SOUTH GONDAR ZONE, ETHIOPIA

M.Sc. Thesis

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DETERMINANTS OF TECHNICAL EFFICIENCY OF MAIZE PRODUCTION OF SMALLHOLDER FARMERS; THE CASE OF FOGERA DISTRICT, SOUTH GONDAR ZONE, ETHIOPIA

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MASTER OF SCIENCE IN AGRICULTURE

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By

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June, 2017

Gondar, Ethiopia

As thesis research advisor, I hereby certify that I have read and evaluated this thesis prepared under my guidance by **YIMENU KASSA** entitled **"DETERMINANTS OF TECHNICAL EFFICIENCY IN MAIZE PRODUCTION OF SMALLHOLDER FARMERS; THE CASE OF FOGERA DISTRICT, SOUTH GONDAR ZONE, ETHIOPIA"** and I recommend that it be submitted as fulfilling the thesis requirement.

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As members of the Board of Examiners of the M.Sc. thesis open defense examination, we certify that we have read and evaluated the thesis prepared by Yimenu Kassa and examined the candidate. We recommend that the thesis be accepted as fulfilling the thesis requirements for the degree of Master of Science in Agriculture (Agricultural Economics).

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Final approval and acceptance of the thesis is contingent upon the submission of final copy of the thesis to council of graduate studies (CGS) through the departmental graduate committee (DGC or SGC) of the candidate.

DEDICATION

I specially dedicate this thesis manuscript to my beloved Mother **Birchiko Worku (Enana)**, who devoted her life in nursing and educating me with affection and love which played great role in the success of my life and to my beloved uncle **Baye Worku** for his sincere love, commitment and who has stood by me and encouraged me throughout the entire period of my study.

STATEMENT OF THE AUTHOR

By my signature below, I declare and confirm that this thesis is my own work. I have followed all ethical principles of research in the preparation, data collection, data analysis and completion of this thesis. All academic matter that is included in the thesis has been given recognition through citation. I affirm that I have cited and referenced all sources used in this document. Every serious effort has been made to avoid any plagiarism in the preparation of this thesis.

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Date: June, 2017

ABBREVIATIONS AND ACRONYMS

AE	Allocate Efficiency
ACSI	Amhara Credit and Saving Institution
CSA	Central Statistical Agency
DAP	Di Ammonium Phosphate
DEA	Data Envelopment Analysis
EE	Economic Efficiency
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
Ha	Hectare
Kg	Kilogram
Ln	Natural Logarithm
LR	Likelihood Ratio
MDE	Man Day Equivalent
MLE	Maximum Likelihood Estimator
MoARD	Ministry of Agriculture and Rural Development
OLS	Ordinary Least Squares
Qt	Quintal
SE	Standard Error
SFM	Stochastic Frontier Model
STD	Standard Deviation
TE	Technical Efficiency
TLU	Tropical Livestock Unit
VIF	Variance Inflation Factor
VRS	Variable Returns to Scale

BIOGRAPHICAL SKETCH

The author was born from his father Ato Kassa Guangul and his mother W/o Birchiko Worku in February, 1991 in Fogera District, South Gonder Zone of Amhara Regional State. He attended His elementary and secondary school at Arbegnoch Elementary School and Tikur Anbessa Senior Secondary School in Addis Ababa from 2001 to 2010. He attended his Preparatory School in Dagmawi Minilik Preparatory School in Addis Ababa from 2011 to 2012. He then joined Addis Ababa University of Agriculture in 2013 and graduated with Bachelor of Science Degree in the field of Agricultural Economics in July 2015.

After graduation, he directly joined University of Gondar for his postgraduate study in the field of Agricultural Economics in 2016.

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ABSTRACT

Ethiopian agriculture is characterized by low productivity. As a result the country has been a scene of poverty and persistent food insecurity. To solve this problem studying the level of technical efficiency becomes more important. The main inspiration of efficiency and productivity studies are the need to investigate and understand the forces that drive maize technical efficiency in order to analyze. Therefore, this study was conducted in Fogera district of South Gondar zone during the production season of 2015/16 to measure the level of technical efficiency and identify socio-economic factors affecting the efficiency of smallholder farmers in maize production. A three stage sampling technique was employed to select 120 maize growing smallholder farmers. Descriptive, inferential statistics and stochastic production functions were employed. The results of the study indicated that the average and standard deviation of the maize production in the sample smallholder farmers were 12.6 quintals per hectare and 5.72, respectively. The Stochastic Production Frontier (SPF) result revealed that DAP, Urea and maize plot size were found to be significantly influencing maize production at 5%, 1% and 5% probability level, respectively. Farmers could increase maize yield by using more of these inputs. The result of the study further showed that there was difference in technical efficiency among maize producers of the study area. The estimated gamma parameters (discrepancy ratio), which measures the relative deviation of output from the frontier level due to inefficiency, was about 84%. This implies that about 84% of the total variation in maize output was due to technical inefficiency effects. The estimated mean level of technical efficiency of maize producers was about 73% while return to scale (RTS) was 0.94%. Based on the results, it was concluded that there existed room for increasing maize output by 27% through efficient use of existing resources and technology. The socio-economic variables that exercised important role for variations in technical efficiency positively were education, improved seed and credit access. Nevertheless, participation in off-farm income, slope and fragmentations were found to increase inefficiency significantly among smallholder farmers. Finally, the calculated marginal effects shows that, ceteris paribus, the use of improved maize seed increase technical efficiency by 7.2% while off-farm income participation reduce technical efficiency by 7.1%. The findings obtained in this study could be quite useful to policy makers. Policy interventions should focus more on timely supply of DAP, Urea, improved seed and socioeconomic significant variables such as education, credit access and slope to improve farmers' efficiency in production of maize.

Key words: *Technical efficiency, Maize production, Stochastic frontier, Fogera district*

1. INTRODUCTION

In this part of the thesis, background, statement of the problem, objectives, research questions, significance of the study, scope and limitation of the study of the thesis were discussed briefly.

1.1. Background

The economy of Ethiopia is largely based on agriculture, agriculture accounts for 46.6% of the gross domestic product (GDP) contributions, 80% of exports earnings, 85% of total employment and 70% of industrial raw materials supplies. Ethiopia has one of the fastest growing economies in the world and it is Africa's second most populous country. The country has over 90 million that growing at the rate of 2.9%. According to MoFED, (2012) 85% of Ethiopians' livelihood depends on agriculture. An area of 1.12 million square kilometers is endowed with high environmental diversity. It is characterized by low productivity, periodic drought, soil degradation caused by overgrazing, deforestation, high population density, and poor infrastructure, smallholder subsistence farming, and instability of production mainly related with farming and traditional and primitive production system(CSA, 2014).

According to World Bank, (2014), Agricultural productions are dominated by smallholder farmers that operate on farms of less than one hectare. In the highlands, the average landholding has fallen from 0.5 ha in the 1970s to only 0.2 ha by 2014 and accompanied by a lower marginal productivity of labor that is estimated to be close to zero. As many as 4.6 million people need food assistance annually. Yet agriculture is the country's most promising resource. A potential exists for self-sufficiency in grains and for export development in livestock, grains, vegetables, and fruits. As a result, agriculture always get due emphasis in national economic strategies of the government for a long period of time (WFP, 2010).

Maize was originated in America and it is the world's third most important food crop next to rice and wheat. It was introduced to Ethiopia during the late 16th or early 17th century. Since its introduction, it has gained much importance and at present stands first in total annual grain production and second in terms of area coverage among cereals in Ethiopia (FAO, 2014). It is also Africa's second most important food crops, after cassava, it is grown in a wide range of environment. Per capita consumption of maize in Africa is highest particularly in eastern and

southern Africa. Maize is processed to offer various product ranges, which include whole maize meal flour, sifted maize meal, vegetable oil, flour for confectionery, dough, corn flakes, snacks and crackers, starch converted to process sugars like glucose syrup and dextrose (Kpotor, 2012).

Ethiopia is one of the world's centers of genetic diversity in crop germplasm produces more of maize than any other crops (CSA, 2014). Maize is Ethiopia's staple crop and is widely grown in most part by smallholder farmers throughout the country. In 2012/13, maize production was 42 million qt, 40% higher than teff and 75% higher than wheat production. With an average yield of 17.4 qt per hectare (equal to 32 million qt grown over 1.8 million hectares) from 2010 to 2013, maize has been the leading cereal crop in Ethiopia since the mid-1990s in terms of both crop yield and production (Rashid *et al*., 2010). However, a study by the Xinshen, 2010 in Ethiopia reveals that the number of farmers engaged in maize cultivation and Eight million smallholder farmers are involved in maize production during 2012/13 production season. When maize production compared to 5.8 million for *teff* and 4.5 million for sorghum which are, the second and third most cultivated crops in Ethiopia, respectively (Wondimu, 2013).

In the year 2013/14 meher season, cereals contributed 84.69% (144.96 million qt) of the grain production in Ethiopia. From which maize, wheat, *teff* and sorghum made up 22.97%, 14.83%, 17.69% and 16.38% of the grain production, respectively. The average yield of cereals namely maize, wheat and *teff were* 22.24, 17.46 and 12.22 qt/ha, respectively (CSA, 2014). Moreover, the Sasakawa Global 2000 project has convincingly demonstrated the potential of available technology to dramatically increase maize production in Ethiopia (Wondimu, 2013).

Maize is a major crop in South Gondar areas of Amhara region of Ethiopia. Farmers grow maize mainly to consume its green cob as an additional meal. They also use it to make different traditional food items like corn flour, porridge, bread, corn meal, for brewing beverage alcohol, livestock feed, corn oil and ethanol production. Whereas, in major maize producing areas of South Gondar area, maize grain is used to make almost all kinds of traditional dishes with or without mixing with other crops. However, due to its scarcity, the utilization of green maize Stalk was limited to feed cattle, particularly draught animals, dairy cows and physically weak animals. It is estimated that 20.72 ton per hectare of maize stalk can be produced (Geta *et al.,* 2013).

Despite the efforts directed at improving maize production over the years, low productivity remains a major challenge in agricultural sub-sector. Hence, the average national on farm level yields of 21 qt per ha compares unfavorably with on farm field trial yields of 50-60 qt /ha and on research field yield 80-110 qt/ha (Dawit *et al.*, 2010). As a result, efforts towards development of maize in South Gondar have been focused on development and dissemination of high yielding varieties to raise productivity of smallholder farmers (FAO, 2011). This means technological advances generated through research fail to be translated into increasing efficiency and resource productivity (Geta *et al.,* 2013).

For the Fogera district, enhancing the total production and productivity is not an option rather it is a must and give the first priority. Production and productivity can be basically boosted using two ways. The first method is through increased use of inputs or improvement in technology given some level of input. The other option of improving productivity is to enhance the efficiency of smallholder farmers, given fixed level of inputs and technology. This study is mainly concerned about the second option of increasing efficiency of productivity. The measurement of efficiency has remained an area of important research where resources are scanty and opportunities for developing by inventing or adopting better technologies are dwindling (Alemayehu, 2010). Therefore, this study was intended to measure the technical efficiency of maize producer smallholder farmers and identify its determinant factors in the Fogera district.

1.2. Statement of the Problem

The main inspirations of efficiency studies were the need to investigate and understand the forces that drive maize technical efficiency. Whether the future prospects of any potential agricultural policy are concerned with a sustainable or a more intensive agricultural production, the study of individual farm efficiency is essential in order to maximize the anticipated benefits of such a policy. Most Ethiopian farmers are smallholders and land is a limiting factor of production besides many other scarce resources (Wondimu, 2013).

According to Endalkachew (2012), in highlands of Ethiopia, the demand for land has been increasing significantly in the last three decades. Available evidences show that over the years, the total land holding per household is becoming smaller and smaller. With 2.9% population increasing and consequent degradation of natural resources, the opportunity to increase smallholders' productivity through area expansion is almost nil. Evidence, especially

in developing agricultural economies where resources and technologies are scarce, measuring efficiency is highly important to improve production and productivity with a given level of resources. The presence of inefficiency not only limits the gains from the existing resources, it also hinders the benefits that could arise from the use of improved technological inputs. One of the enormous challenges in the drive to increase food to feed the growing population was to raise productivity and efficiency in the agricultural sector (FAO, 2014).

However, a study by the Mariano (2010), over the years much attention has been given to the development and the adoption of new technologies. This initiative is believed to enhance farm output and increase income levels of farmers. However, growth in output cannot only be achieved through technological innovation but also through the efficiency in which such technologies are used. This has made researchers and policy makers recognize the importance of efficiency as a way of fostering production. Empirical evidence shows that the gap between actual and potential outputs could be closed by utilizing minimum inputs to achieve a possible maximum output (Kassim, 2010).

The presence of gaps in efficiency means that output could be increased without requiring additional conventional inputs and without the need for new technology. If this is the case, then empirical measure of technical efficiency in maize production is necessary in order to determine the extent of the gains that could be obtained by improving performance in agricultural production with a given technology (Kpotor, 2012).

The role of efficient use of scarce resources in promoting agricultural production has long been recognized and has motivated considerable research into the extent and sources of efficiency differentials in smallholder farmers. Empirical evidence suggests that improving the productivity of smallholder farmers is important for economic development because small holder farmers provide a source of employment and a more equitable distribution of income (Wassie, 2012).

Given the various agricultural program and policies implemented over the years to raise smallholder farmers' efficiency and productivity, becomes imperative to quantitatively measure the level of technical efficiency and identify its determinants and policy options available for raising the present level of efficiency (Abu and Quintin, 2013). According to the survey made by the (IFPRI), in Amhara region, average maize yields are 70% higher when improved seed and fertilizer are used as compared to the local seed without fertilizer. It

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indicates the existence of more than 40% yield potential for further improvement based on results from research stations (Diao, 2010).

Gains in agricultural output through the improvement of efficiency levels are becoming particularly important now days. The opportunities to increase farm production by bringing additional forest land into cultivation or by increasing the utilization of the physical resources have been diminishing. In addition, reducing the existing inefficiency among smallholder farmers can prove to be more cost effective than introducing new technologies as a means of increasing agricultural output and smallholder farmer's income (Gemeda, 2011).

In the study area maize is the leading cereal in area cultivation. As the population size increases the option of expanding agricultural production in general and maize production in particular through expansion in cultivated land was not be possible. Under such conditions increasing production through area expansion (extensive cultivation) is limited and the only possible way to increase production and productivity is to use intensive production methods (CSA, 2014). Therefore, the study attempts to see if there is a room to increase maize production by improving the technical efficiency level of smallholder farmers in South Gondar zone and to identify which explain the difference in technical efficiency among maize producing smallholder farmers.

As a result, examining the optimum utilization of the seeds, DAP, urea, herbicide and labor utilized with respect to productivity of maize could be considered as a one-step forward towards bridging the existing information gap. This has a paramount contribution to gain deep insight to understand in maize production by indicating opportunities for possible policy intervention towards improving maize productivity. Furthermore, in the study area there was lack of related research on technical efficiency on maize production of the smallholder farmers and determinants of the variability in the efficiency levels among smallholder farmers.

1.3. Objectives of the Study

The general objective of the study was to assess determinants of technical efficiency in maize production of smallholder farmers in Fogera district of South Gondar Zone.

Specific objectives of the study were:
1. To estimate the level of technical efficiency of smallholder farmers in maize production and,
2. To identify the determinant of technical efficiencies in maize production among smallholder farmers in the study area.

1.4. Research Questions of the Study

The study set out to answer the following questions:
(1) What is the level of technical efficiency of maize producing smallholder farmers?
(2) What are the determinants for the variation of technical efficiency among the Maize producer smallholder farmers? These were important questions that guided the study in identifying the demographic and socio-economic variables influencing the maize productivity in the study area.

1.5. Significance of the Study

A technical efficiency study plays a significant role in providing useful information regarding to technical inefficiencies in production and helps to identify those factors, which are associated with inefficiencies that may exist. It may help to indicate the possibility of increasing production without increasing the consumption of inputs or decreasing the level of inputs. This would help to reduce total production cost without decreasing the level of output. In other words, specific farm efficiency study helps to determine the level to which smallholder farms were using the existing technologies efficiently; the potential for raising output with the existing technology; and eventually the possibility to raise productivity by improving both efficiency and technology adoption. Hence, improving smallholder farmers' efficiency is an alternative source of growth of the agricultural sector. Such studies would benefit the economy by determining the extent to which it is possible to raise productivity by improving efficiency, with the existing resource base and available technology.

Therefore, results of this study generated adequate information on the issues which helps to designing different policies and interventions for improvement of efficiencies and the identification of the extent of inefficiencies as well as the factors associated, mitigate the problem of food insecurity, used as a reference and initiate other researchers who are interested in conducting different research works from different perspectives on the field which will improve the performance of maize production and improve domestic and international competitiveness of the smallholder farmers of the district and country as well. Conducting this study in the targeted district would give tremendous timely technical contribution to indicate the way out to improving agricultural productivity of the smallholder farmers.

1.6. Scope and Limitation of the Study

The study was conduct in Fogera district of South Gondar zone of Amhara region. The study was undertaken to estimate the level of technical efficiency of maize production and identify factors that causes efficiency differentials among maize producing smallholder farmers during 2015/16 production year. The study used cross-sectional data obtained from 120 sample smallholder maize producer farmers using semi structured interview schedule. Fogera district was selected for the study based on the potentiality of maize production in South Gondar Zone. The results of the study were based on a small sample of smallholder farmers in three kebeles out of twenty four rural kebeles and which may not necessarily be representative of the entire smallholder farmers due to a shortage of budget, time and facilities. The study was also conducted using cross-sectional data. This may be affected by the specific climate of the year in the study area. Agriculture is dependent on weather condition. Thus, the results of cross-sectional data do not show the change over time. Smallholder farmers do not keep records of inputs and output. Therefore, smallholder farmers survey by itself was difficult and to get reliable data especially on smallholder farmers land holding, volume of production, number of livestock as well as other variables which have socio-economic implications may not always be free from error since smallholder farmers can only recall the most recent information.

On the other hand, the efficiency score of the frontier method were only relative to the best firms in the sample, the inclusion of extra firms (say from overseas or other efficient firms in the country) may reduce the efficiency scores (Coelli and Battese, 2006). Thus, the efficiency scores of the study were relative values of the best smallholder farmer in the study area. This

efficiency score might be reduced if more efficient smallholder farmers from other area were included in the study. Likewise it could increase if less efficient smallholder farmers were included. Despite these limitations, the study is expected to generate valuable information which may be of great use to different stakeholders.

Smallholder farmers in the study area produce a variety of crops ranging from annual to perennial food and cash crops. Cereals, among food grains, were the dominant ones. Therefore, the study focuses on maize crop production under the rain fed agriculture during the main (meher) season.

1.7. Organization of the Thesis

Since the aim of this study was to examine the technical efficiency of smallholder farmers maize producers in Fogera district, the study was structured as follows: Chapter two literature reviews, chapter three discusses the methodology, including methods of data collection and analytical techniques used to analyze the data. Chapter four presents the socio economic characteristics of the survey households and presents models results of the study, estimated level of technical efficiencies and determines factors of inefficiencies. Chapter five presents summary, conclusion and recommendations of the study.

2. LITERATURE REVIEW

In this part of the thesis, overview of maize production in the world and in Ethiopia, concept of efficiency, approaches of efficiency measurement, models for measuring technical efficiency, measurement approach in analyzing determinants of technical efficiency, empirical studies on efficiency in the World and in Ethiopia and conceptual frameworks of technical efficiency were discussed briefly.

2.1. Overview of maize production in the World and its economic importance

The origin of the word maize is in Arawac tribes of the indigenous people of the Caribbean. The discovery of fossil pollen and cave corncobs in archaeological areas support the position that maize originated in Mexico. The spread of maize from its center of origin in Mexico to various parts of the world has been remarkable and rapid with respect to its evolution as a cultivated plant and as a variety of food products. European explorers took maize to Europe and later traders took maize to Asia and Africa (Neumann *et al*., 2010).

Different types of maize are grown throughout the world, with one important difference being color. Maize kernels can be different colors ranging from white to yellow to red to black. Most of the maize grown in the United States is yellow, whereas people in Africa, Central America, and the southern United States prefer white maize. Yellow maize is not popular in Africa for reasons associated with the perception of social status. Apparently it is associated with food aid programs and is perceived as being consumed only by poor people. Also, the feed industry consumes mostly yellow maize in the manufacture of animal feed. But the main reason for the preference for white maize is simply one of tradition. People used to eat white product in these countries, usually the white is the better (CSA, 2011).

Maize is the global leading cereal in terms of production, with 1,016 million metric tons produced on 184 million hectares globally. Maize is produced globally across temperate and tropical zones and spanning all continents. The subtropical maize in the low and middle income countries that provide 64% of total maize production and where maize plays a key role in the food security and livelihoods of millions of poor farmers (FAO, 2014).

The increasing demand for maize and its global advance implies that by 2023, maize will account for the greatest share (34%) of the total crop area harvested. This poses particular challenges to the global capacity to sustainably supply the volumes of maize needed particularly in low and middle income countries. Indeed, rising demand has often expanded the maize area in these countries and brought new land into cultivation instead of sustainable intensification and increasing yields. Crop area thereby often expands into more marginal lands with potential threats to crop diversity, forests, and erodible hill slopes. Across the developing world, maize production systems are increasingly diverse and present a gradient of extensive to more intensive systems, with varying implications and concerns in relation to soil erosion, soil fertility loss, land degradation (acidification and salinity), reliance on fossil fuel-derived energy for synthesis of nitrogen fertilizers and pesticides, and rural transformation (e.g., competition for or lack of rural labor, all often aggravated by climate change induced by global warming. Climate change poses significant risks to future crop productivity as temperatures rise, rainfall patterns become more variable and pest and disease pressures increase. Climate change affects the poorest populations most in terms of food security. The number of malnourished children in sub-Saharan Africa is expected to increase as the severity of climate change increases (Neumann *et al*., 2010).

However, there are viable solutions that can be deployed to meet these significant challenges. While there are fewer opportunities for land expansion, there are significant avenues for improved germplasm and sustainable intensification to raise and stabilize yields and to close yield gaps. Sustainable intensification means simultaneously raising yields, increasing the efficiency with which inputs are used and reducing the negative environmental effects of food production. Improved agricultural technology is seen as an essential strategy for increasing agricultural productivity, achieving food self-sufficiency and alleviating poverty and food insecurity among (Dawit, 2010).

2.2. Overview of maize production in Ethiopia and its economic importance

Maize, a member of the grass family, is believed to have originated in Mexico, and to have been introduced to Ethiopia in the 1600s to 1700s. For example, in highland Ethiopia, Seminic speakers called maize "*yabaher mashela*" which in Amharic means "sorghum from the sea" (FAO, 2014). This name leads us to conclude that maize must have come from coastal areas to the interior highlands. In Ethiopia, maize grows under a wide range of environmental conditions between 500 to 2400 meters above sea level. Maize is Ethiopia's

leading cereal in terms of production, with 6 million tons produced in 2012 by 9 million farmers across 2 million ha of land (Meher season). Over half of all Ethiopian farmers grow maize, mostly for smallholders, with 75% of all maize produced being consumed by the farming household. Currently, maize is the cheapest source of calorie intake in Ethiopia, providing 20.6% of per capita calorie intake nationally. Maize is thus an important crop for overall food security. Maize is also used for making local beverages. Additionally, the leaves and stalks are used to feed animals and the stalks are used for construction and fuel. A small quantity of the grain produced is currently used in livestock and poultry feed, and this is expected to increase with the development of the livestock and poultry enterprises in the country. The green fodder from thinning and topping is an important source of animal feed and the dry fodder is used during the dry season. Moreover, the crop has potential uses for industrial purposes, serving as a starch, a sweetener for soft drinks, an input for ethanol fuel production and oil extraction, etc (CSA, 2014).

As compared to other cereals, maize can attain the highest potential yield per unit area. World average yield for maize is about 4.5 tons/ha and that of developed countries is 6.2 tons/ha, with a harvest of 10 tons /ha being common. The average yield in developing countries is 2.5 tons/ha. In Ethiopia the national average yield is about 3.0 tons/ha. While significant gains have been made in maize production over the past decade, there remains large potential to increase productivity. Ethiopia is already a significant maize producer in Africa, and this role could be further enhanced. Currently, Ethiopia is the fourth largest maize producing country in Africa, and first in the East African region (FAO, 2014). Maize is mainly grown in the four big regions of the country: Oromia, Amhara, SNNP, and Tigray. Oromia and Amhara contribute to almost 8% of the maize produced in 2014. While there have been significant gains made in maize production over the past decade, there is still a significant opportunity to further increase productivity. It is also significant that Ethiopia produces non-genetically modified white maize, the preferred type of maize in neighboring markets. Maize is Ethiopia's most important cereal in terms of production, with 6 million tons produced in 2012 by 9 million farmers across 2 million hectares of land. From 2001 to 2011, maize production increased by 50%, due to increases in both per hectare yields (+25%) and area under cultivation (+20%). Estimates indicate that the current maize yield could be doubled if farmers adopt higher quality inputs and increasing the efficiency with which inputs are used (CSA, 2014).

2.3. Concepts of Technical Efficiency

Efficiency: It is the act of achieving good result with little exertion of efforts. It is the act of harnessing material and human resources and coordinating these resources to achieve better management goal (Beckhman *et al,* 2010). Farrell *et al.,* (1985) distinguished between types of efficiency such as Technical Efficiency (TE), Allocative Efficiency (AE) and Economic Efficiency (EE), by which it can be measured in terms of all these type of efficiency. The appropriate measure of technical efficiency is input saving which gives the maximum rate at which the use of all the inputs can be reduced without reducing output.

Technical efficiency: it reflects the ability of a firm, country or university to obtain maximal output from a given set of inputs and technology. It is measured by the output of the firm relative to that which it could attain if it were 100% efficient, i.e. if it lay on the frontier itself, and is therefore bound between zero and one (Nyagaka, 2010).

Technical efficiency is concerned with the efficiency of the transformation of inputs to physical output. That is, for efficient production, farm output should lie on the envelope curve, or production function, which traces out the maximum quantities of output from varying quantities of inputs under a given technology. When technical efficiency is defined in terms of maximum output from a given bundle of measured inputs, only those farmers who are technically efficient is operate on the production frontier. A farmer whose input- output performance falls below the production function is technically inefficient (Dlamini *et al.,* 2010).

According to the neoclassical definition of technical efficiency, firms are efficient and whatever inefficiency comes in the process of production is due to external shocks or statistical noise which is entirely beyond their control. Furthermore, a production process is technically efficient if and only if it yields the maximum possible output for a specified technology and input set. The concept of efficiency can be explained more easily using input or output oriented approaches. The input oriented measure of efficiency addresses the question "by how much can input quantities be proportionally reduced without changing the output quantities produced?"(Coelli and Battese, 2006). A farm can be on or above the unit iso-quant on the input per unit of output space and cannot be below or to the left to it. A departure from the unit iso-quant indicates technical inefficiency and the more a farm were far from the unit iso-quant, the more it is inefficient.

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Allocative efficiency deals with the extent to which farmers make efficiency decisions by using inputs up to the level at which their marginal contribution to production value is equal to the factor cost. Technical and allocative efficiencies were components of economic efficiency (Kilic *et al,*. 2009). Economic efficiency is concerned with the realization of maximum output in monetary term with the minimum available resources.

One firm is more technically efficient if it produces a level of output higher than another firm with the same level of input usage and technology. Measures of technical efficiency give an indication of the potential gains in output if inefficiencies in production were to be eliminated. The ideas of production function can be illustrated with a farm using n inputs: X_1, X_2. X_n, to produce output Y. Efficient transformation of inputs into output is characterized by the production function $F(X_i)$, which shows the maximum output obtainable from various inputs used in production (Oyewo, 2011).

The belief that traditional farmers are "efficient but poor" as hypothesized by is based on the assumption that farmers were profit maximizers. This has attracted the attention of a number of development economists and it was assumed that farmers, by maximizing utility, prevent any major inefficiency in the allocation of traditional factors and operate on the most superior production function available to them (Nyagaka, 2010).

FAO, 2014 defines smallholder farmers with "limited resource endowments, relative to other farmers in the sector". Geta *et al.,* (2013) also characterize a smallholder farmer "as a farmer (crop or livestock) practicing a mix of commercial and subsistence production or either, where the family provides the majority of labor and the farm provides the principal source of income".

Mariano, (2010) mentions two ways to explain the failure of the maximization behavior process by considering the vast number of economic variables. First, the marginal revenue products of some or all factors might not be equal to their marginal costs and firms with such a problem were said to be allocatively inefficient. Second, production may occur on the interior of the production possibilities set and this problem is referred to as technical inefficiency. Different views have been entertained in applying the maximization behavior process to an evaluation of smallholder farmers.

2.4. Approaches to Efficiency Measurement

Following Lovell, (1993), the productivity of a production unit can be measured by the ratio of its output to its input. However, productivity varies according to differences in production technology, production process and differences in the environment in which production occurs. The main interest here is in isolating the efficiency components in order to measure its contribution to productivity. Producers are efficient if they have produced as much as possible with the inputs they have actually employed and if they have produced that output at minimum cost. Technical efficiency is measured as the ratio between the observed output and the maximum output, under the assumption of fixed input. However, allocative (or price) efficiency refers to the ability to combine inputs and outputs in optimal proportions in the light of prevailing prices, and is measured in terms of behavioral goal of the production unit like, for example, observed v_s optimum cost or observed profit v_s optimum profit. The input approach if one is considering the ability to avoid waste by producing as much output as input usage allows, i.e. we evaluate the ability to minimize inputs keeping outputs fixed and the output approach if one is considering the ability to avoid waste by using as little input as output production allows, i.e. we evaluate the ability to maximize outputs keeping inputs fixed. However, it is important to be aware that efficiency is only one part of the overall performance as reported in Figure 1 (Worthington and Dollery, 2000).
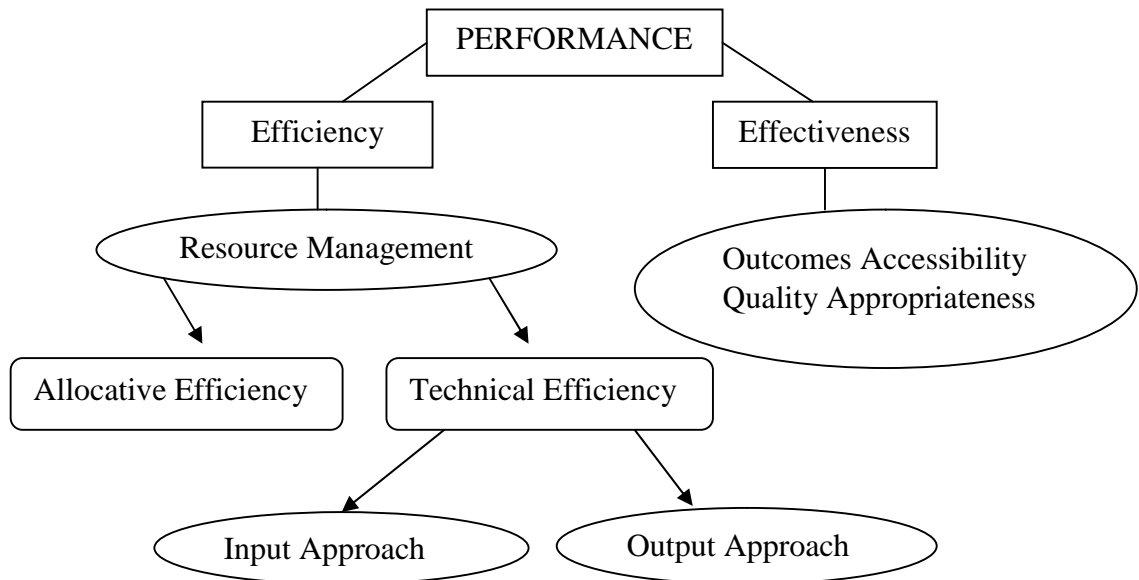
Figure 1: Framework for Efficiency assessment
Source: Worthington and Dollery, 2000

The concept of production efficiency in general and the distinction between technical and allocative efficiency in particular is further explained using two approaches input-oriented and output-oriented approaches.

2.4.1. Input-Oriented Concept of Efficiency

Original idea of representing the technology in a convex iso-quant is an input-oriented measure of efficiency. Farrell (1985) illustrated the idea of input oriented efficiency using a simple example of a given firm. He used two factors of production, capital (K) and labor (L), to produce a single output (Y), and face a production function, $Y = F(K, L)$, under the assumption of constant returns to scale, where the assumption of constant return to scale was help us to present all necessary information on a simple is quant.

The input oriented approach addresses the question "by how much a production unit can proportionally reduced the quantities of input used to produce a given amount of output?" (Coelli and Battese, 2006). The two factors per-unit output that a firm uses can be presented on the two dimensional input/input space. The iso-quant SS' (Figure 2) represents the various combinations of the two input variables that at least a firm might use to produce a unit output. This is an iso-quant that defines the input-per-unit of output ratios associated with the most efficient use of the input to produce the output involved.
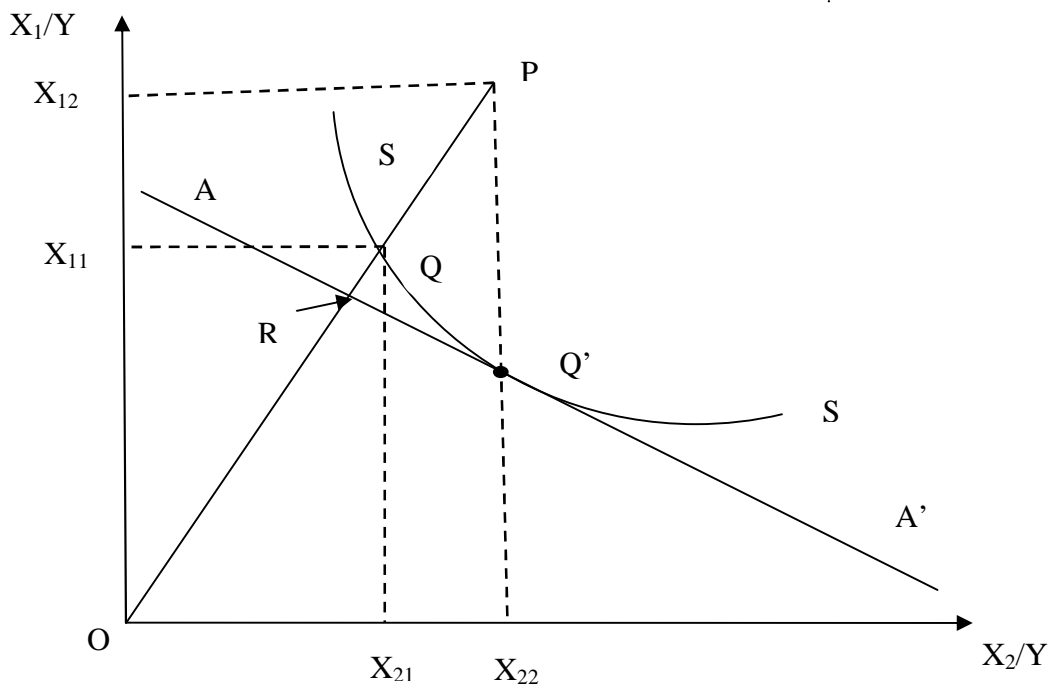
Figure 2: Input-oriented illustration of technical and allocative efficiency
Source: Herrero and Kebelecoe, (2004)

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In an input-oriented measure of efficiency, both allocative and technical efficiencies of a firm fall on or above the unit iso-quant of the input per unit of output space and cannot be below or to the left of it. For instance, as illustrated in figure 1 above a firm producing at P uses inputs X_{12} and X_{22} to produce a unit output and firm Q uses X_{11} and X_{21} amounts of inputs to produce the unit output given by the iso-quant curve SS'. The ratio $(X_{12} - X_{11})/X_{12}$ which is equal to $(X_{22} - X_{21})/X_{22}$ is the proportion by which firm P has over used the inputs and this measures the level of technical inefficiency of the firm. All firms that were located on the unit iso-quant SS' were technically efficient and all production inputs were optimally used (Herrero and Kebelecoe, 2004).

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 iso-quant may not necessarily be allocatively efficient, since allocative efficiency requires additional information on both inputs and output prices. The point of tangency between AA' (the iso-cost line) and SS' (the iso-quant curve) is the least cost combination of inputs and thus is the allocatively efficient point of a given firm. Departure from the line AA' represents the degree of allocative inefficiency and the value for point Q is given by the ratio RQ/OQ. The distance RQ represents the reduction in production costs that would occur if a firm is to produce at both allocatively and technically efficient point Q', instead of at the technically efficient, but allocatively inefficient, point Q.

According to (Herrero and Kebelecoe, 2004) mathematically the technical efficiency (TE) and allocative efficiency (AE) of a firm operating at P is represented as follows

$$\text{TEp} = \frac{OQ}{OP} \qquad\qquad\qquad (1)$$

$$\text{AEp} = \frac{OR}{OQ} \qquad\qquad\qquad (2)$$

Economic efficiency (EE) is therefore the product of the two efficiencies.

$$\text{EE} = \text{AEp} \times \text{TEp} = \frac{OR}{OQ} \times \frac{OQ}{OP} = \frac{OR}{OP} \qquad\qquad (3)$$

2.4.2. Output-Oriented Concept of Efficiency

While the input oriented approach answers the question by how much the input use can be reduced without affecting the level of output, in the output oriented approach one can alternatively answer the question by how much can output be increased without increasing the amount of inputs used (Coelli and Battese, 2006). (Figure 3) illustrates the output-oriented approach of efficiency measurement using a production possibility curve that shows the possible combination of two outputs (Y_1 and Y_2) one can produce given input X and the level of technology.
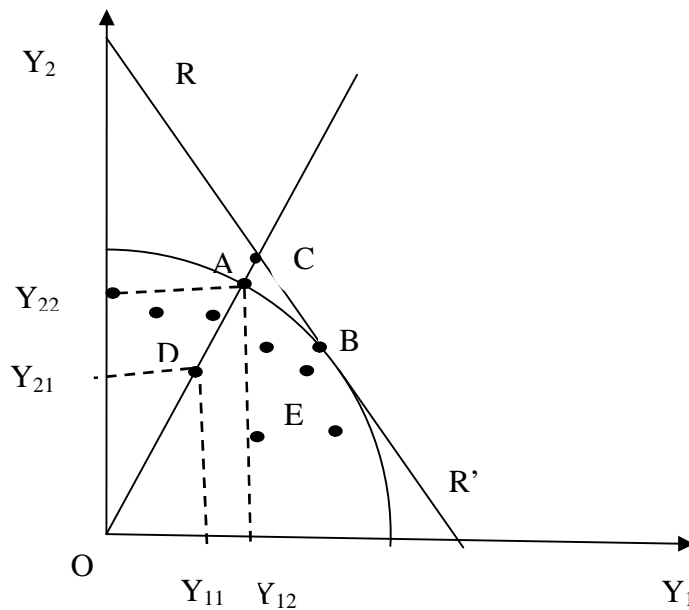
Figure 3: Output-oriented illustration of technical and allocative efficiency

Source: Coelli and Battese, (2006)

Given the production possibility curve, a producing unit can then be located either exactly on the production possibility curve or below it. All producers on the curve have attained the maximum combination of Y_1 and Y_2 that can be produced given the input level and state of technology. But firms located below the curve were said to be inefficient. For instance, given the fixed amount of input and level of technology under constant return to scale Firm D is producing lesser amount of both outputs than A. There is a possibility for firm D to increase the level of outputs Y_1 and Y_2 from Y_{11} to Y_{12} and from Y_{21} to Y_{22}, respectively, without requiring extra inputs. This proportion $(Y_{22} - Y_{21})/Y_{22}$ which is equal to $(Y_{12} - Y_{11})/Y_{12}$ is the level of technical inefficiency of firm D, and thus the technical efficiency of D is given by

$$TE = (1 - \frac{Y_{12} - Y_{11}}{Y_{12}} = \frac{OD}{OA} \qquad (4)$$

It can be also define the concept of allocative efficiency using the output-oriented approach if we have the price information of the two products by drawing the iso-revenue line RR', Moreover, for those firms whose marginal rate of substitution between product Y_1 and Y_2, the slope of iso-revenue line were equal to Y_2/Y_1, assisting them to produce output proportionally considering their prices (Headey *et al.,* 2010).

According to Brazdik, (2006) the allocative inefficiency is given by the ratio of the distance between the production possibility curve and the iso-revenue curve is between the origin and the iso-revenue curve. The allocative efficiency of firm A, for instance, is given by the ratio OA/OC which is equal to the allocative efficiency of firm D. The allocative efficiency of all those firms on line OC is equal to one. We can also measure the economic efficiency of a firm as a product of both the allocative and technical efficiencies of the output oriented approach as follows.

$$EE = \left(\frac{OD}{OA}\right) * \left(\frac{OA}{OC}\right) = \frac{OD}{OC} \qquad (5)$$

The above theoretical measures of efficiency assumes its applicability when the production function of a given farm enterprise is known. However in practice, the iso-quant is never known. Hence, the iso-quant that represents the efficient points must be estimated from sample data. But the question here is how to estimate production frontiers that represent efficient points of production. The following paragraph gives a brief highlight on the models used in measuring efficiency.

2.5. Models for Measuring Technical Efficiency

Technical efficiency measurements were carried out using frontier methodologies, which shift the average response functions to the maximum output or to the efficient firm. Many empirical studies of efficiency were devoted in analyzing what impact a given model specification has on the efficiency measurements. Various issues concerning to model specification were still debatable. The selection of specific frontier model depends upon many considerations such as the type of data, cross-sectional or panel data, the underlying behavioral assumptions of firms, the relevance to consider and extent of noise in the data and the objective of the study (Coelli and Battese, 2006).

The frontier methodologies have been widely used in applied production analysis. This popularity is evidenced by the proliferation of methodological and empirical frontier studies over the last two decades. Despite these wide arrays of applied work, the extent to which empirical measures of efficiency were sensitive to the choice of methodology remains a matter of controversy (Nyagaka, 2010).

When discussing the performance of firms or decision-making units, it is common to describe them in terms of 'productivity' or 'efficiency'. Though 'productivity' and 'efficiency' were not precisely the same things, both of them were good indicators to evaluate the performance of firms / production units. Efficiency is defined as the ratio of observed output to the maximum potential output that can be attained from given inputs while productivity is the ratio of the output to the input (Nikaido, 2004).

The large number of frontier models that have been developed based on Farrell's work can be classified into two basic types: parametric and non-parametric. Parametric frontiers, which rely on a specific functional form, can be separated into deterministic and stochastic. The parametric models were basically estimated based on econometric methods and the nonparametric technical efficiency model, often referred to as data envelopment analysis (DEA), involves the use of linear programming method to construct a non-parametric 'piecewise' surface (or frontier) over the data (Coelli and Battese, 2006).

2.5.1. Non parametric frontier estimation methods

One of the methods of measuring efficiency in agricultural production is the non parametric approach of the Data Envelopment Analysis (DEA). It was first introduced by Farrell *et al.,* (1985) based on the Farrell's approach. The principal and most commonly used non-parametric frontier model in the analysis of Efficiency is Data Envelopment Analysis (DEA). Based on Farrell *et al.,* (1985) influential work was the first to introduce DEA approach to estimate efficiency. Since its introduction, the approach has served as the corner stone for all subsequent developments in the nonparametric approach to the measurement of technical efficiency.

The DEA frontier is both non-parametric and non-stochastic. As pointed out by several authors (Coelli and Battese, 2006; Headey *et al.,* 2010), DEA strategy has several advantages. It is a nonparametric technique that does not require a prior specific functional form for the production frontier since it does not impose any a priori parametric restrictions on the underlying frontier technology (because doesn't necessitate any functional form to be specified for the frontier methodology) and doesn't require any distributional assumption for the technical efficiency term. In addition, multiple outputs and multiple inputs without necessarily being aggregated can be handled in DEA technique. Furthermore, it is possible to identify the best practice for every decision-making unit under consideration and estimate the output or cost gap of inefficient firms to be fully efficient. Regarding its potential weaknesses, however, apart from its sensitivity to extreme observations, a hypothesis testing at the first stage of DEA is not possible. Moreover, the technique attributes all deviations from the frontier (best practice) to resource use inefficiency.

The two basic DEA models were named after the respective researchers to first introduce them: the Charnes Cooper Rhodes and the Banker Charnes Cooper models (Biforin *et al.,* 2010). The type of their envelopment surfaces and orientations normally distinguishes the two models. The envelopment surfaces include the form depicting a constant-return-to-scale (CRS) or variable return-to-scale (VRS) represented in the Bio models, respectively (Kasim, 2010). The main advantages of the DEA approach were that it can handle multiple inputs and multiple outputs and that it avoids the parametric specification of technology as well as the distributional assumption for the inefficiency term. However, because DEA is deterministic and attributes all the deviations from the frontier to inefficiencies, a frontier estimated by DEA is likely to be sensitive to measurement errors and other noise in the data (Coelli and Battese, 2006).

The above DEA model represents input-oriented CRS efficiency measurement. This can also be done for output- oriented problem. In addition, the model can be relaxed to consider different sets of problems such as VRS, to make it fit for scale inefficiencies that could be allocative and economic efficiency. The constant return to scale (CRS) assumption is only appropriate when all firms were operating at optimal scale. Imperfect information, government regulation and constraints on finance etc may cause a firm to be not operating at optimal scale. The use of VRS specification permits to compute technical efficiency devoid of these scale efficiency effects.

$$SE = TE_{CRS}/TE_{VRS} \qquad (6)$$

The VRS analysis is more flexible than the CRS analysis; the variable return to scale (VRS) technical efficiency measure (Θ^{VRS}) is equal or greater than CRS measure (Θ^{CRS}). The relationship is used to obtain a measure of SE (Scale Efficiency).

$$SE = \theta_i^{CRS}/\theta_t^{VRS} \qquad (7)$$

Where, SE=1 indicates SE (CRS) and if SE<1 indicates scale inefficiency. Scale inefficiency is due to the presence of either increasing or decreasing returns to scale, which can be determined by solving non-increasing returns to scale.

In these models, the identification of determinants of inefficiency effects requires a second stage analysis. In the second stage, efficiency indices was regressed upon socioeconomic variables that can be estimated through identification of factors associated with technical efficiencies. However, the main criticism of DEA is that it assumes all deviations from the frontier were due to inefficiency. Due to this, nonparametric frontier methodology may exaggerate inefficiencies and hence outliers may have profound effect on the magnitude of inefficiency was (Headey *et al.,* 2010). Hence, the application of DEA becomes limited.

2.5.2. Parametric frontier estimation methods

Parametric frontier model can further be classified into deterministic and stochastic frontier methods. Typically, both models use econometric techniques to estimate the parameters of pre specified functional forms. However, the deterministic model assumes that any deviation from the frontier is due to inefficiency, while the stochastic approach allows for statistical noise (such as measurement error, weather, industrial action, etc) which, are beyond the control of the decision making unit(in this case the household head). This parametric model uses econometric technique for efficiency analysis which relies on a specific functional form. The parametric models were basically estimated based on econometric methods (Coelli and Battese, 2006).

2.5.2.1. The deterministic frontier approach

One of the most commonly used efficiency measurement under the deterministic approach was proposed by Farrell *et al.,* (1985) is called deterministic parametric approach. He proposed computing a parametric convex hull of the observed input-output ratios with the help of Cobb-Douglas production function. He noted the advantage of specifying the functional form in measuring degrees of inefficiency in expressing the frontier in a mathematical form. The main feature of the deterministic frontier is that it assumes that all firms share a common family of production, cost and profit frontiers and all variations in the firm's performance were attributed to variations in the firm's efficiency.

The main criticism of the deterministic frontier model is that it does not account for possible influence of measurement error and other noise upon the shape and positioning of the estimated frontier (Coelli and Battese, 2006). All observed deviations from the estimated frontier were thus, assumed to be the result of technical inefficiency. Therefore, the method sums up all the effects of exogenous shocks together with measurement errors and inefficiency. Due to the limitations of the deterministic parametric frontier approach led to the development of the other variant of the deterministic measurement approach, a model known as deterministic statistical frontier. This model was explicitly proposed by Afriat (1972) which involves statistical techniques and assumptions to be made about statistical properties of the frontier model. The deterministic parametric frontier approach is formulated with the production behavior of firms. It can be expressed as;

$$Y_i = f(X_i; \beta) \exp(-U_i) \qquad i=1, 2, \ldots\ldots.N \qquad (8)$$

Where $f(X_i;)$ is a suitable functional form, is vector of unknown parameters, U assesses the socioeconomic, institutional and technological factors that were responsible for low production and productivity of the firm. U_i is a nonnegative random variable associated with technical inefficiency of the ith firm which implies that $\exp(-U_i)$ is bounded between 0 and 1 while Y_i is the vector of output. Those observations on U were independently and identically distributed, and that X is exogenous (independent of U). Afriat (1972) proposed a two parameter Beta distribution for U, which is the model to be estimated by maximum likelihood method.

The technical efficiency of the ith firm is indicated by the factor by which the actual (observed) production deviates from the frontier (potential) output. Hence, the ratio of the

observed output for the ith firm, relative to the potential output, defined by the frontier function, given the input vector, x_i, is used to define:

$$TE = \frac{y_i}{\exp(x_i\beta)} = \frac{\exp(x_i\beta - \mu_i)}{\exp(x_i\beta)} = \exp(-\mu_i) \qquad (9)$$

Nyagaka, (2010) developed the probabilistic frontier to the outliers in the above deterministic estimation approaches. The deterministic model considers that any deviation from the frontier is due to inefficiency. Hence, when there is high random error on the data, the inefficiency estimates was exaggerated as compared to other models, which take into account random errors.

In general, most empirical studies on technical efficiency analysis in agriculture used stochastic frontier model due to the varying nature of agricultural output, which is affected by natural hazard, climatic condition and measurement errors that could attribute to the presence of noise in the data. Hence, most recent studies on technical efficiencies in agriculture have used stochastic frontier model to account for random noise.

2.5.2.2. Stochastic frontier model

The stochastic frontier approach which was introduced in order to overcome the problem associated with random error in the deterministic approach an alternative estimation method by Meeusen (1977) and Aigner et al., (1977), reversed the conventional belief that deviations from the production frontier were due to inefficiency of the producing units (i.e, factors under the control of the producers, which may not be true). Hence, stochastic estimations of technical efficiency incorporate a measure of random error, which is one component of the composed error term of a stochastic production frontier. So, it made possible to find out whether the deviations in production from the frontier output is due to firm specific factors or due to external random factors. The stochastic Production Frontier was developed by adding a symmetric error term (v_i) to the non negative error term of the equation in (1) as:

$$\ln(y_i) = F(x_i; \beta) + v_i - u_i \qquad i = 1, 2, ..., n \qquad (10)$$

In this equation the v_is' are assumed to be independent and identically distributed random errors following a normal distribution with zero mean and variance σ_v^2. The random error accounts for measurement error, and other external factors such as climatic changes in production process which is out of the control of the producer; whereas the u_is' were the

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technically inefficiency terms which were associated with the technical inefficiency of the firms.

In the prediction of firm level of technical efficiencies, Coelli and Battese, (2006) pointed out that the best predictor of $\exp(-\mu_i)$ is obtained by:

$$E[\exp(-\mu_i)/e_i] = \frac{1-\phi(\sigma_A + \gamma e_{i/\sigma_A})}{1-\phi(\gamma e_i/\sigma_A)} \exp(\gamma e_i + \sigma^2/2) \qquad (11)$$

Where $\sigma_A = \sqrt{\gamma(1-\gamma)\sigma_s^2}$; $e_i = \ln(y_i) - x_i\beta$; (.) is the density function of a standard normal random variables which can be estimated by maximum likelihood once the density function for μ_i is specified.

The primary advantage of the stochastic frontier production function is that it enables one to estimate farm specific technical efficiencies. The measure of technical efficiency is equivalent to the production of the ith farm to the corresponding production value if the farm effect U is zero. However, the estimation of efficiency using stochastic method requires a prior specification of functional form and needs distributional assumptions (half-normal, gamma, truncated, etc.) for the estimation of U_i, which cannot be justified given the present state of knowledge (Coelli and Battese, 2006).

The stochastic frontier production model incorporates a composed error structure with a two sided symmetric term and a one-sided component. The one-sided component reflects inefficiency, while the two-sided error captures the random effects outside the control of the production unit including measurement errors and other statistical noise typical of empirical relationships. Hence, stochastic frontier models address the noise problem that characterized early deterministic frontiers. Stochastic frontiers also make it possible to estimate standard errors and to test hypotheses, which were problematic with deterministic frontiers because of their violation of certain maximum likelihood (ML) regularity conditions Schmidt, (1976).

In stochastic frontier method, technical efficiency is measured by estimating a production function. Different production functions such as Cobb-Douglas, Trans log, Transcendental, and Quadratic etc. can be used to estimate the frontier. The Trans log and Cobb-Douglas specifications were commonly used functional forms to estimate the frontier; but both have their merits and demerits. Therefore, the method avoids the imposition of unwarranted structures on both the frontier technology and the inefficiency component that might create distortion in the measurement of efficiency (Shafiq and Rehman, 2000).

Given the above facts, the stochastic frontiers method was used in this study. The choice is made on the basis of the variability of agricultural production, which is attributable to climatic hazards, and insect pests. Moreover, all information gathered on production is usually inaccurate since small farmers do not have updated data on their farm operations. In fact, the stochastic frontiers method makes it possible to estimate a frontier function that simultaneously takes into account the random error and the inefficiency component specific to maize producing farmers.

2.6. Measurement Approach in Analyzing Determinants of Technical Efficiency

The literature offer two approaches in analyzing the determinants of technical efficiency using stochastic frontier production function. These are two stage estimation approach and single stage estimation approach.

2.6.1. Two stage estimation approach

The two stage approach involves the estimation of the technical efficiency effects from models and regressing these on a set of farm and farmer; specific characteristics. In this approach, the two-stage estimation procedure is used to estimate stochastic production to derive efficiency scores. After the efficiency scores are derived in the first stage, the second stage follows where the derived efficiency scores are regressed on explanatory variables using ordinary least square (OLS) methods or Tobit regression. This approach, though widely used, it implies that the inefficiency effects which are assumed to be independently and identically distributed in the estimation of the stochastic frontier are a function of the farm specific effects in the second stage, thus violating the assumption that the efficiency effects are identically distributed (Coelli and Battese, 2006).

The above approach has been criticized on the grounds that the firm's knowledge of its level of technical inefficiency affects its input choices; hence inefficiency may be dependent on the explanatory variables. The inefficiency effects would only be identically distributed if the coefficients of the farm specific factors were simultaneously equal to zero. It is possible to overcome this problem by the use of a single stage maximum likelihood approach (Coelli and Battese, 2006).

2.6.2. Single stage simultaneous approach

The single stage approach advocates a one stage simultaneous estimation approach in which the inefficiency effects were expressed as an explicit function of a vector of farm-specific variables. The technical inefficiency effects were expressed as

$$U_j = Z_j \delta \qquad (12)$$

Where for farm j, Z is a vector of observable explanatory variables affecting technical efficiency and is a vector of unknown parameters. Thus, the parameters of the frontier production function were simultaneously estimated with those of an inefficiency model, in which the technical inefficiency effects are specified as a function of other variables. The one stage simultaneous approach could be estimated in FRONTIER (Coelli and Battese, 2006). The program provides basic parameters and coefficients for the technical inefficiency model. Hence several factors, including socioeconomic and demographic factors, plot-level characteristics, environmental factors, and non-physical factors are likely to affect the efficiency of smallholder farmers.

Based on its advantage, the one-step approach was used in this study. In effect, relative to the two-step approach, the one-step approach presents the advantage of being less open to criticism at the statistical level, and helps in carrying out hypothesis testing on the structure of production and degree of efficiency.

2.7. Empirical Review on Measurements of Technical Efficiency in the World

Determinants of technical efficiency can be socio-economic characteristics and resource endowment. It can also be institutional factors which were found to affect level of farmers' technical efficiency. These factors can either affect technical efficiency positively or negatively and most of those factors were location specific i.e. a factor, which has positive impact on technical efficiency at a particular locality at one time was found to appear with the opposite effect or become irrelevant in another locality. It follows from these findings that it cannot identify universally defined factors either hindering or enhancing or not affecting technical efficiency of farmers (Hasan, 2011). Based on this fact, some of the major recent empirical studies on measuring and determining level of technical efficiency of smallholder farmers in different countries were summarized in the following paragraphs.

Isaac, (2011) used a cross sectional data and estimated the technical efficiency of maize producing-farmers in Oyo State, Nigeria and further examined the factors that determined the differential in efficiency index. Stochastic frontier production model was used in the analysis to determine the relationship between the maize output and the level of input used in the study area. The farm size and seed where found to influence efficiency of maize production positively and significantly. Hence, the study confirmed that more land could still be brought for maize production in the area with the existing level of input use.

Essilfie *et al.,* (2011) estimated the levels of technical efficiency 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 technical efficiency 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 technical efficiency 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.

Beckhman *et al.,* (2010) estimates a stochastic frontier production function to examine the determinants of technical efficiency in rice farming in Bangladesh. The analysis of the determinants of technical efficiency revealed that the age and education of the household heads, availability of off-farm incomes, land fragmentation, extension visits, were the major factors that caused efficiency differentials among the farm households studied. Hence, the study proposed strategies such as providing better extension services and farmer training programs, reducing land fragmentation and raising educational level of the farmers to enhance technical efficiency.

Olowa and Olowa (2010) estimated sources of technical efficiency among smallholder maize farmers in Osun State of Nigeria using a Cobb-Douglas stochastic production frontier approach. The researcher found that smallholder maize farmers in Nigeria are inefficient. The result showed that inefficiency declines on plots planted with hybrid seeds and for those controlled by farmers who belong to households with membership in a farmers association.

Sekhon *et al.,* (2010) analysis of technical efficiency was done in different regions of India as well as in the state of Punjab to show how different regions have adopted the latest

technology. They estimate farm level TE using stochastic frontier production function analysis. According to their study, the main drivers of efficiency were experience in agriculture and age of a farmer. The TE has shown a wide variation across regions. The average TE has been found maximum in the central region (90%), followed by south-western and sub-mountainous regions.

Goodness *et al.,* (2010) investigated the technical efficiency of traditional and hybrid maize farmers in Nigeria. As estimates obtained from the distance frontier approaches indicated hybrid seed was found to have positive and significant impact technical efficiency. Other policy variables that had significant impact on technical efficiency included education, extension services, credit and land. The result reinforced the need for further investment in agricultural research and development for increased productivity, food security and poverty reduction in Nigeria.

Huynh and Mitsuyasu, (2011) made an effort to measure the TE of rice production and identified some determinants of TE of rice farmers in Vietnam. They used Vietnam household living standard survey and analyzed using stochastic frontier analysis method. In their study using the Cobb-Douglas production functional form, the mean level of TE was found to be 81.6%. According to their study, the most important factors having positive impacts on TE levels were intensive labor in rice cultivation, irrigation and education.

Abba, (2012) a study done on the technical efficiency of sorghum production and its determinants used stochastic frontier production function which incorporates a model of inefficiency effects. He used farm level data collected from a sample of 100 sorghum farmers in Hong local government area of Adamawa state. According to his study, land, seed, and fertilizer were the major factors that influence changes in sorghum output and education, extension contact and household size were major explanatory variables that had significant effects on the technical inefficiency among the sorghum producers. The TE of farmers varied from 15.62 to 92.14% with a mean TE of 72.62%. The implication of the study is that efficiency in sorghum production among the farmers could be increased by about 27% through better use of land, seed and fertilizer in the short term given the prevailing state of technology.

Luke, Atakelty and Amin, (2012) a study done in an analysis of technical efficiency in Northern Ghana using bootstrap DEA, the average TE of crop production was found out to be 77.26%. This indicates as nearly 23% production loss is due to technical inefficiency. The

estimated scale efficiency was 94.21%. They used a two stage estimation method, which they found hired labor, geographical location of farms, gender and age of head of household significantly affect TE

2.8. Empirical Evidence on Production Efficiency and Its Determinants in Ethiopia

A number of efficiency analysis have been conducted by different researchers in the country with the aim of identifying the sources of inefficiencies and their policy implications so as to improve the future development endeavors through enhancing the prevailing technical efficiencies. Most of the studies have specified the Cobb-Douglas type production function and commonly estimated parameters by using the MLE procedure and also used the SPF methodology. The survey indicated that stochastic frontier modeling is the most dominant.

Getachew and Bamlak, (2014) analyzed the technical efficiency of small holder maize growing farmers in Horo Guduru Wollega Zone of Oromiya regional state. Cobb-Douglas stochastic production function model was used for their analysis. The average estimated technical efficiency for smallholder maize producers ranges from 6% to 92% with a mean technical efficiency of 66%. This implies that technical efficiency in maize production in the study area could be increased by 34% through better use of available resources, given the current state of technology. The educational level of the farmer, age of house hold head, land fragmentation, extension services, engagement in off-farm activities, and total land holding of the farmer were the major socio-economic factors influencing farmer's technical efficiency and maize output.

Wondimu Tesfaye (2013) undertook a study on determinants of technical efficiency in maize production of smallholder farmers in Dhidhessa Woreda, Illubabor zone, Ethiopia. The Stochastic Production Frontier (SPF) result revealed that area allocated under maize and chemical fertilizers appeared to be significantly influencing maize production. The average technical efficiency was 86 percent while return to scale was 0.96 percent. Based on the results, it was concluded that there existed scope for increasing maize output by 14 percent through efficient use of existing resources. Hence if the experience and knowledge of farm household heads that attained higher technical efficiency were shared among other farmers in the woreda, an additional output of 2060 quintals of maize could have been produced given 7550 ha of land allocated to maize production during the study period in the woreda. Thus,

ample scope existed to realize higher maize output with existing resources and level of production technology. The socio-economic variables that exercised important role for variations in technical efficiency were age, education, improved seed, training on maize production and labor availability in the household.

Hassen, (2012) used parametric methods of efficiency measurement and the result revealed that most farmers in the study area were not efficient suggesting that efficiency improvement was one of the possible avenues for increasing agricultural production with available resource and technology. The mean TE of the household calculated from parametric approach of SFA were 62%. Farm size, livestock ownership, labor availability, off-farm income participation, total household asset, total household consumption expenditure and improved technology adoption were found to determine production efficiency.

Shumet, (2011) used survey data collected by Tigray Microfinance in the year 2009 to estimate small holder farmers' TE and its principal determinants. He used both descriptive and econometric methods of analysis. In his study, he has tested the functional form, existence of inefficiency, and the joint statistical significance of inefficiency effects. The maximum likelihood parameter estimates showed that except labor all input variables have positive and significant effect on production. According to the study, the mean TE of farmers was 60.38% implying that output in the study area can be enhanced by 39.62% using same level of input and the current technology. The estimated stochastic frontier production function revealed that education of household heads, family size, Ownership of plot; credit access, crop diversification, and land fertility were found to have a positive and significant effect on efficiency. In contrast, households' age, dependency ratio, livestock size, and off-farm activity affect efficiency negatively and significantly.

Wassie, (2012) empirical evidence obtained from small scale wheat seed producer farmers in Ethiopia prevails that, on average, the total wheat seed production can be enhanced by nearly 20%, keeping inputs and current production technology constant. Alternatively, the mean TE of sampled households was 79.9%. It used Cobb Douglas production function, to determine elasticity of inputs and the level of efficiency of each producer. He applied a two-stage estimation method. He used the estimated level of efficiency as dependent variable in the Tobit model which was used to determine factors that affect efficiency. Accordingly, interest in wheat seed business (dummy) and total income positively and significantly affect TE while total expenditure has a negative and significant effect.

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Geta *et al.,* (2013) a study undertaken in southern Ethiopia with the objective of assessing productivity and technical efficiency of smallholder farmers, based on the data collected from 385 randomly selected farmers, indicated as there was significant level of inefficiency among maize producing farmers. They used a two stage estimation technique, translog production function to determine the levels of TE followed by Tobit regression model to identify factors influencing TE. The model result depicted that productivity of maize was significantly influenced by the use of labor, fertilizer, and oxen power. The mean TE was found to be 40 percent and important factors that significantly affected the TE were agro-ecology, oxen holding, farm size and use of high yielding maize varieties.

The above investigation has been conducted in different parts of Ethiopia and other countries in different agro-climatic and socio-economic conditions on the determinants of technical efficiency. More importantly, the literature review above prevails that Cobb Douglas production function has wider application in analysis of efficiency. These determinants of technical efficiency do also vary spatially and temporally. Likewise, given the importance of maize production in Fogera district, this study was examines the determinants of technical efficiency on maize production of smallholder farmers. Moreover, in Fogera district such type of investigations has not been conducted to identify the determinants of technical efficiency of smallholder farmers engaged in maize production. Therefore, this study intends to fill these gaps.

2.9. Conceptual Framework of Technical Efficiency in maize production

A production process involves the transformation of inputs into outputs. In maize production, technical inputs such as seeds, land, herbicides chemical and DAP and Urea fertilizers are combined to produce the maize. The transformation process depends not only on the levels of inputs used, but also on the management practices that the smallholder farmers use to combine these inputs. Management practices used in production represent an amalgam of knowledge and skills that the smallholder farmer has or acquires overtime and characteristics of the farm. The technical inputs and the management practices jointly determine the quantity and quality of maize output produced.

Figure 4 shows the interaction of various factors that were considered to have a various degrees and directions of impact on the level of technical efficiency in smallholder farmers

maize production. Studies, for instance, by Bernadette, (2011) showed that efficiency of production was determined by the host of socio-economic and institutional factors. These factors directly or indirectly affect the quality of management of the smallholder farm's operator and, therefore, are believed to have impact on the level of technical inefficiency of smallholder farms. According to Ruth, (2011), a range of factors like distinctiveness of smallholder farms, management, physical, institutional and environmental aspects could be the cause of inefficiencies in the production process of the smallholder farmers.
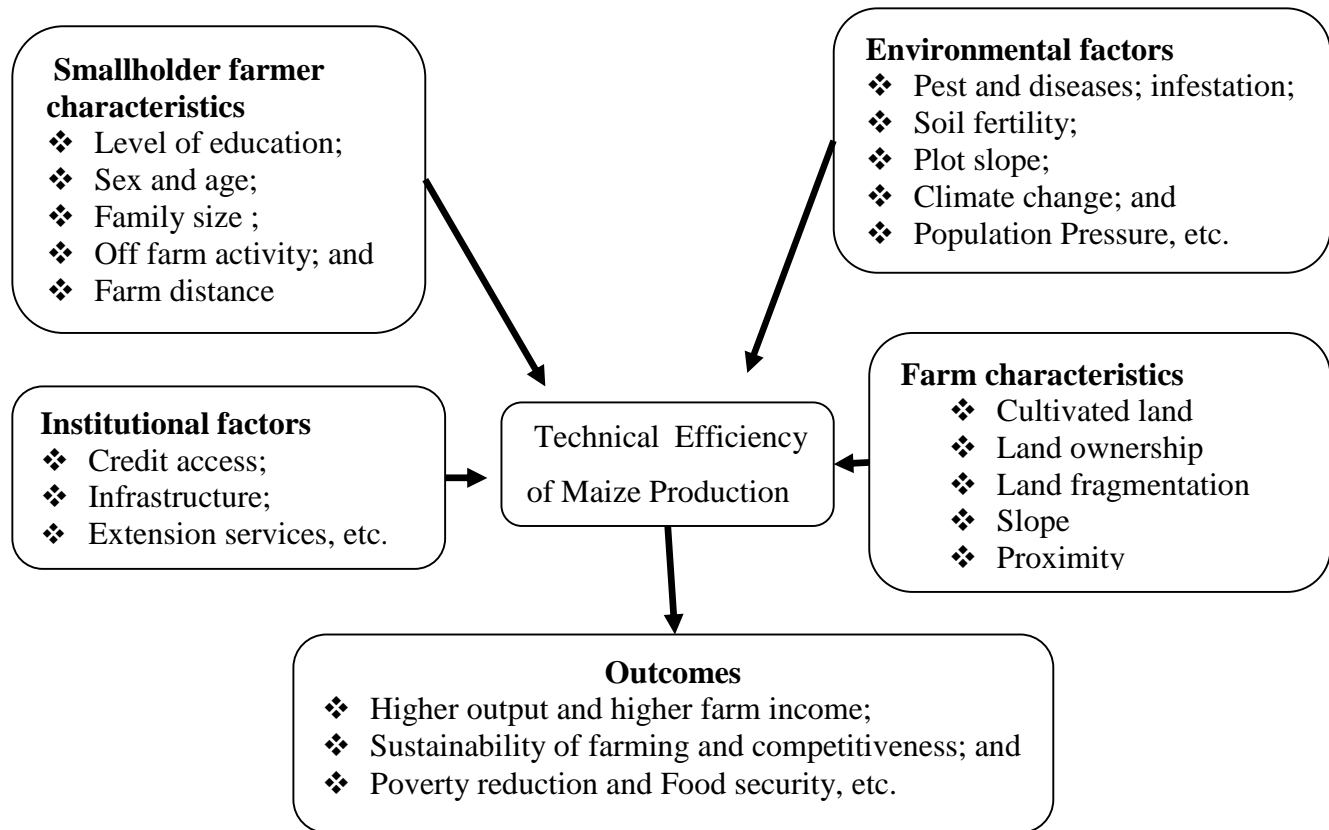
Figure 4: Conceptual framework of Technical Efficiency in maize production

Source: Own conceptualization

Institutional factors such as credit access, land fragmentation, infrastructure and input accesses can have significant effect on the resource use efficiency of maize production. Access to credit provides incentive and means to access improved crop technology via improving smallholder farmers' liquidity and the affordability of the inputs required for production. Therefore, institutional arrangements which target access to credit, infrastructure and access to education are important variables that can substantially affect resource use efficiency and productivity.

Environmental factors such as Pest and diseases infestation, Soil fertility, Plot slope, Climate change, weather condition, resource depletion, and population pressure can affect resource use efficiency in maize production. According to Rudra *et al.,* (2014) Pest and diseases infestation, Soil fertility, Plot slope, climate change and other environmental pressures cause a major threat to productivity growth. Biforin *et al.,* (2010) explained that differences in efficiency between smallholder farmers can be explained by environmental characteristics, such as soil quality, vegetation cover, altitude, climate, rainfall and temperature among others. Therefore, environmental factors should be considered to address problems related to resource use efficiency and productivity of smallholder farmers.

Smallholder farmer Characteristics such as level of smallholder farmer's education, sex, age, family size and off-farm income can affect resource use efficiency in maize production and influences their management capacity. Kwabena *et al.,* (2014) mentioned that farmers with more education are more likely to adopt new technologies. Efficiency variations between smallholder farmers can also be explained by the farm location. Farm characteristics such as cultivated land, land ownership, land fragmentation, slope and proximity also are important because in most farming systems are significant variations (Ruth, 2011). Thus, factors related to smallholder farmer characteristics and farm characteristics are included in the analysis believing that they have effects on technical efficiency productivity of the smallholder farmers.

The final element of the framework is the outcomes effect of the interaction of various external (institutional and environmental factors) and internal (farmer and farm characteristics) variables for further reforms. It indicates whether the interventions or changed practices have impacts in the smallholder farmer. According to Bernadette, (2011) the outcome effects of technical efficiency can be positive or negative.

3. RESEARCH METHODOLOGY

In this part of the thesis, study area description, sampling technique and sample size determination, data collection method, variable selection, measurement units and hypotheses and data analysis method were discussed briefly.

3.1. Description of the Study Area

Under this part, location and topography, crop production pattern and maize yield trends and area coverage were briefly discussed as follows.

3.1.1. Location and topography

The study was conducted in Fogera district at South Gondar zone. It is one of from 106 districts as of the Amhara Regional State and found in South Gondar Zone. It is situated at 110 58 N latitude and 370 41 E longitude. Woreta is the capital of the district and is found 625 km from Addis Ababa and 55 km from the regional capital, Bahir Dar. The district is bordered by Libo Kemkem district in the North, Dera district in the South, Lake Tana in the West and Farta district in the East. The district is divided into 29 rural keble Administrations and 5 urban kebeles (FWADO, 2015/16).

Based on 2007 national census conducted by the Central Statistical Agency of Ethiopia (CSA, 2014), Amhara Region has a population of 17,214,056 of which 8,636,875 were men and 8,577,181 were women. Urban inhabitants were 2,112,220 or 12.27% of the total population. With an estimated area of 159,173.66 square kilometers, this region has an estimated population density of 108.15 people per square kilometer. For the entire region 3,953,115 households were counted. This results to an average of 4.3 persons per household. The average family size in urban and rural area is 3.3 and 4.5 persons, respectively.

The total land of the district is 117,414 ha. The current land use pattern includes 44% cultivated land, 24% pasture land, 20% water bodies and the rest for others. The total population of the district is 251,714. The rural population is estimated at 220,421. The proportion of male and female population is almost similar in both rural and urban areas. The number of agricultural households is 44,168. The mean annual rainfall is 1216.3 mm, with Belg and Meher cropping seasons. Its altitude ranges from 1774 up to 2410 meters above sea

level allowing a favorable opportunity for wider crop production and better livestock rearing (FWADO, 2015/16).

Most of the farm land was allocated for annual crops where cereals covered 51,472 ha; pulses cover 9819.98 ha; oil seeds 6137 ha; root crops 1034.29 ha; and vegetables 882.08 ha (CSA, 2014). The major crops grown based on area coverage include teff, maize, finger millet and rice. According to (IPMS, 2014), average land holding was about 1.4 ha with minimum and maximum of 0.5 and 3.0 ha, respectively.

The study area is gets much of the flood water that accumulates around Lake Tana and the two big rivers, i.e., Rib and Gumara. The rivers bring eroded soil from uphill and deposit on the low land plain. The soil seems relatively deep and fertile (CSA, 2014).

Table 1. Land use pattern of Fogera district

Land use	Area (ha)	%
Land planted with annual crops	51472	44
Grazing land	26999	24
Area covered with water (wet land)	23354	20
Infrastructure including settlement	7075	6
Un-productive land (hills)	4375	3.7
Forest land	2190	1.8
Swamp land	1698	1.4
Perennial crops	2190	0.2
Total	**117414**	**100**

Source; FWADO, (2015/16)

Map of the Study Area
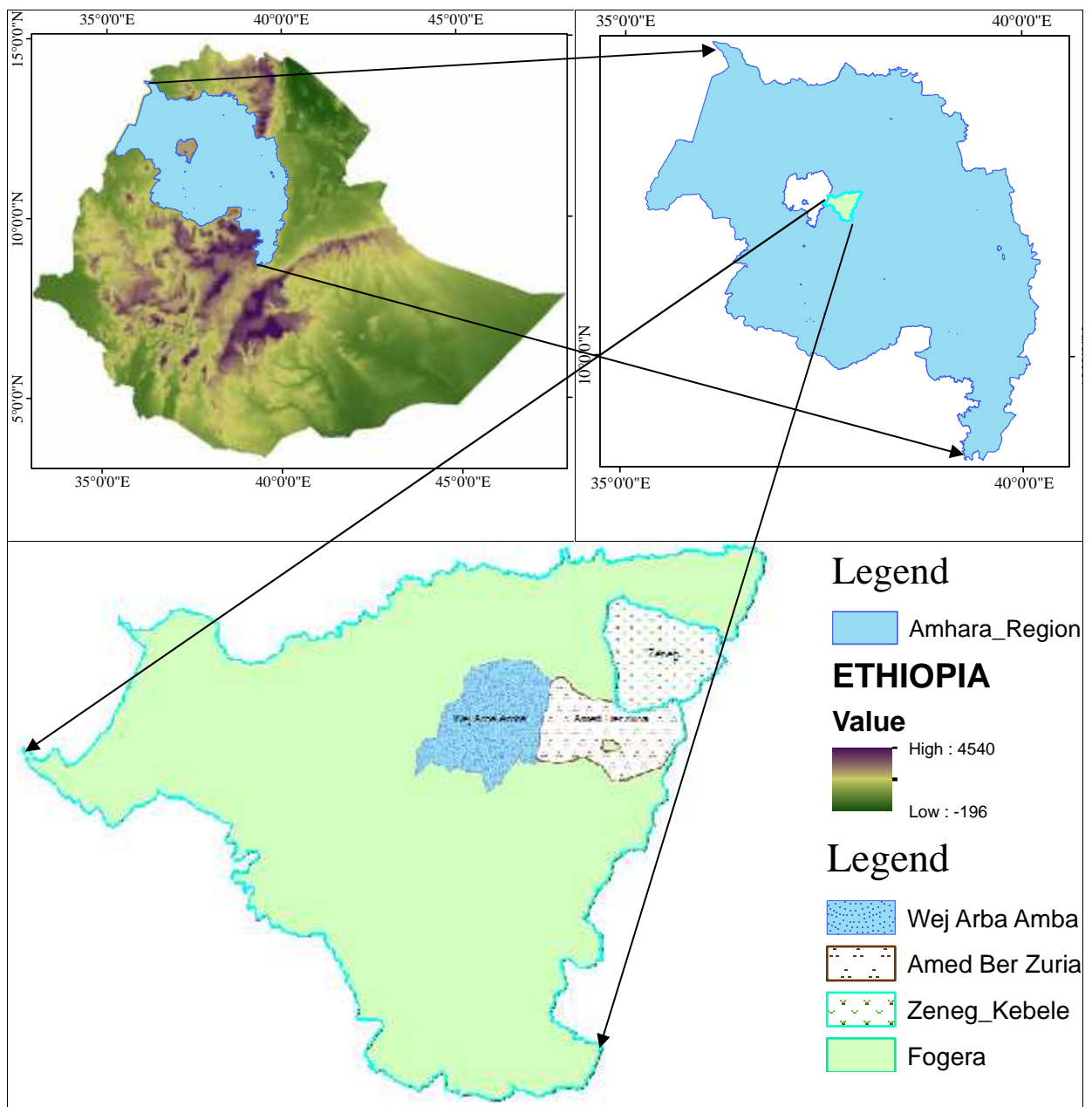
Figure 5**:** Map of the Study Area

3.1.2. Crop production pattern

The major crops produced in the different agro-ecologic zones of the district include several annual and perennial crops. Annual crops include cereals, pulses and oilseeds while perennial crops include fruits such as mango, papaya, lemon. Among staple crops, rice is by far the most important sources of income followed by niger seed as a second important cash crop. Among cereal crops, maize is the major crop produced next to teff (Tefera *et al.,* 2011).

Table 2. Cropping pattern of major crops in Fogera district in (2015/16) production year

Type of crop	Area coverage	
	Hectare	**%**
Maize	7550	22.75
Teff	1023	25.20
Rice	9237	18.6
Barely	1150	7.83
Sorghum	7435	16.31
Bean	2293	6.34
Finger Millet	800	2.97
Total	**29488**	**100**

Source; FWADO, (2015/16)

Maize occupied 22.75% of the total cropped area in Fogera districts during the production year of 2015/16 (Table 2). Amongst cereal crops, teff appeared as the most important cereal crop occupying 25.20%. Among cereal crops, finger millet occupied the minimum area that is only 2.97%. Besides teff, sorghum and Barely were other two cereal crops grown by farmers. Rice was found as the main staple crops cultivated by farmers occupying a substantial proportion of the cropped area which was 18.6%.

3.1.3. Maize yield trends and area coverage

The total production that would have been produced in the district was enhanced by either if the productivity of the smallholder farmers were improving their production efficiency or by using modern technologies or a combination of both. Even though, there has been an increase in the total production of major crops in the district in the past decade, this has been due to increases in area cultivated (Shiferaw *et al.,* 2013). However, given the current technological conditions and the existing pressures on the farm land, pushing the production area further is difficult in the district. Hence, the increase in the production failed to satisfy the growing demand of maize (Wondimagegn, 2010).

As shown in Figure 6, the trend in quantity of maize production in kilogram was increased over time when total area (ha) on average increased. Changes in yield at the smallholder farmers as well as the district level can be driven either by changes in the crop quantity harvested, or by changes in the land area cultivated and harvested. Smallholder farmers have expanded maize cultivated area from 2009 up to 2015 production years, either by switching land under other crops to maize cultivation, or by expanding into previously uncultivated

area. When cultivated area is increased into more marginal lands or by smallholder farmers less experienced with maize, the district's aggregate yields may drop, stay steady, or rise more slowly.
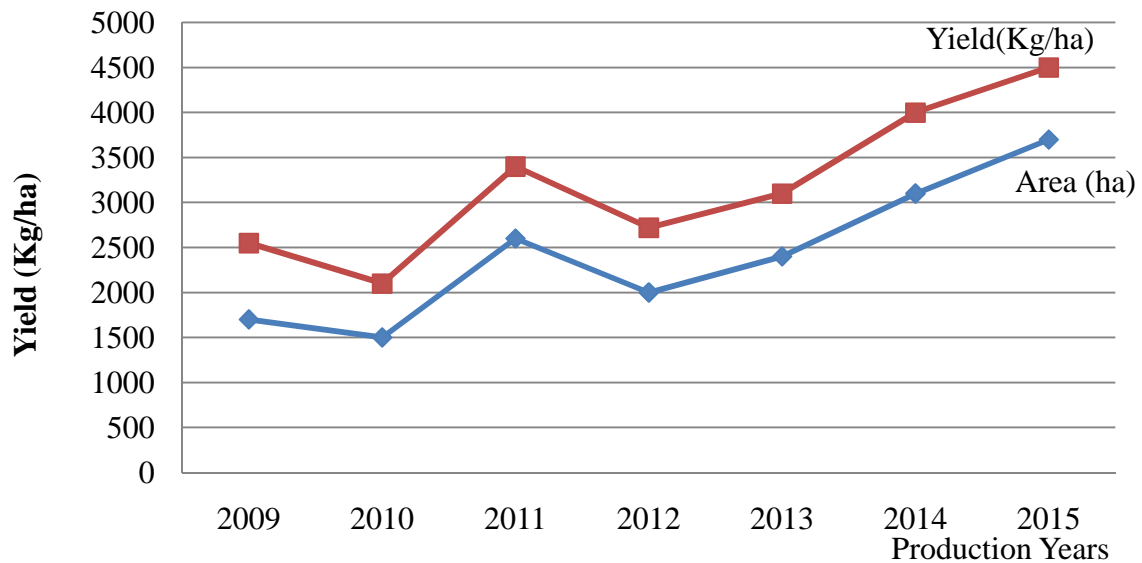
Figure 6: Maize yield trends in Kg/Ha and Area Harvested (2009-2015)

Source; FWADO, (2015/16)

3.2. Sampling Technique and Sample Size Determination

In this study, three stage sampling technique were employed to select 120 sample smallholder farmers. Fogera district consists of 24 rural and 5 urban Kebles Administrations (KAs). In the first stage, out of the total 24 rural (KAs) that participated in maize production of 2015/16 cropping season in the district, 12 Kebeles were selected using purposive sampling technique which were maize cultivation was carried extensively. In the second stage, 3 Kebeles namely Alember zuria, Woj Arba Amba and Zeng were selected using simple random sampling technique. In the third stage, based on a complete list of names of all maize producer smallholder farmers obtained from FWAO, 40, 52 and 28 sample smallholder farmers were selected from Alember zuria, Woj Arba Amba and Zeng, respectively using probability proportional to size (PPS) technique. The existing kebeles share similarities in topography, mixed crop production system and use of technology. The study applied a simplified formula provided by Yamane, (1969) to determine the required sample size at 95% confidence level, degree of variability 0.5 and level of precision 9% are recommended in order to get a sample size which is represent a true population.

$$n = \frac{N}{1+N(e)^2} = \frac{2885}{1+2885(0.09)^2} \approx 120 \tag{13}$$

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Where 'n' is the required sample size, 'N' is total number of smallholder farmers in the selected kebeles (2885) and 'e' is the level of precision/sometimes called sampling error (0.09). The above formula gave 120 sample sizes for the study area. Table 3 shows the list of Kebles, number of smallholder farmers that growing maize in each KA and sample smallholder farmers taken from each KA.

Table 3. Distribution of maize growing smallholder farmers by sample Kebeles

Kebeles	Maize grower	Sample size	%
Alember Zuria	976	40	34
Woj Arba Amba	1251	52	43
Zeng	658	28	23
Total	**2885**	**120**	**100**

Source: FWADO, (2015/16)

3.3. Data Collection Method

Primary and secondary data was collected. To collect primary data from the sample smallholder farmers, semi structured interview schedule was employed. To facilitate the task of data collection, enumerators was recruited from the study areas and was trained. Interview schedule was pretested with the enumerators for one day to ensure that wording and coding matched field situation.

The data pertaining to output obtained and quantity of various inputs used in maize production was collected. That is to say, data was collected on input-output variables such as output obtained in quintal, labor (MDE), oxen (ODE), plot size in ha., fertilizer in kg and seed in kg. In addition, demographic, socio-economic and institutional data such as age, sex, level of education, access to credit, family size, soil fertility, maize plot slope, maize seed varieties and total livestock (TLU) was collected.

Secondary data related to maize production trend and input supply was collected to clarify and support analysis and interpretation of primary data. In addition, secondary data was also obtained from reports of similar studies and information's documented at various office levels of FWAO and other district agricultural office. An important literature on technical efficiency was also accessed from the internet and university of Gondar library.

3.4. Variable Selection, Measurement Units and Hypotheses

In this study, both production efficiency and inefficiency variables were addressed. The identification of important variables used for the estimation of frontier model were selected based on observing the characteristics of maize production of the areas and through review from previous works on efficiency studies.

3.4.1. Definition of input and output variables

Both the explained variable and explanatory variables was used in the stochastic frontier production function.

Output (OUTP): The quantity of maize output produced by the sample smallholder farmers during the 2015/16 production year measured in quintals. This is dependent variable of the production function. Technical efficiencies of maize smallholder farmers were determined by comparing the actual/observed maize output against the frontier maximum output. The following input variables were used as explanatory variables:

Maize Plot Size (AREA): Land used for maize production during 2015/16 production season by each smallholder farmers measured in ha. It belongs to the smallholder farmers, obtained by means of hiring, leasing or through share cropping arrangements. It is expected to determine the efficiency differential of smallholder farmers in the study area. It is important to evaluate whether relatively large smallholder farms were more efficient or not than small ones. As the farm size of a smallholder farmer increases, the production of maize increases. Therefore, it was hypothesized that as the farm size increases, productivity of the smallholder farmers increase (Kifle, 2014; Wondimu, 2013; Endalkachew, 2012; Abba, 2012; Isaac, 2011).

Labor (LAB): This input captures family, shared and hired labor used for different agronomic practices of maize production in the 2015/16 production season. But the differences in sex and age among labor would be expected. Hence, to make a homogeneous group of labor to be added, the individual labor was changed in to Man Days Equivalent (MDE) using the standard developed by (Storck *et al.,* 1991). Therefore, the human labor input was expressed in terms of total MDE. Since harvesting does not affect the level of

maize output unless there is unexpected rain fall, disease, this destroys outputs. Under the smallholder farming system, family labor constitutes the major labor supply to the farm. The amount of available labor supply within a given farming, smallholder farmers were affect production activities. It was hypothesized that the available labor related positively to production efficiency. Given the fact that, the labor is the main input in production, a smallholder farmer that has been more labor can carry out important crop husbandry practices timely (Geta *et al.,* 2013; Wondimu, 2013; Hasssen 2012).

Seed (SEED): It refers to the amount of maize seed and measured the quantity of maize seeds in kilograms (kg) used by each smallholder farmer in 2015/16 cropping season. It is the usage of both improved variety of maize seed and home produced or local maize seeds. Seed is a universal input in all crop-based farming systems and seeding rate affects crop productivity (Kifle, 2014; Wassie, 2012; Isaac, 2011). Hence, it was hypothesized that the quantity of seed determines the seed rate which can have positive influence on maize yield.

Urea and DAP fertilizers (UREA and DAP): Fertilizer is a key input and its application along with other technologies could have a great potential to increase crop productivity. Urea is applied on the farm land once or using split application, but DAP is usually applied during planting time only. As input variables, the total amount of Urea and DAP used in Kg for the 2015/16 year maize production was considered in this study. Amount of fertilizer was expected to have positive effect on yield, but when under dose happens it can lead to low yield or total crop failure. Therefore, application of Urea and DAP fertilizer at sowing time and after would increase the level of production. Therefore, the efficiency level of the smallholder farmer was positive (Kifle, 2014; Bakary, 2014; Bekele, 2013; Ruth, 2011; Abba, 2012; Alemayehu, 2010).

Oxen power (OXPW): Draught power used for different farming activities for maize production is measured in oxen day. Hence, oxen power was measured using the total amount of oxen days allocated for different activities of maize production in 2015/16 production season. The total head of draft animals the smallholder farmer own can greatly affect farming activities. If the smallholder farmer has enough pairs of oxen with which to plow, he can accomplish his operations timely and with good quality (especially land preparation and sowing) (Kifle, 2014; Bekele, 2013; Endalkachew, 2012; Geta *et al.,* 2013). Hence, it was hypothesized that the more heads of oxen of smallholder farmers have the more productive.

Herbicide (HERB): As input variables, the total amount of herbicide used in litter (Lt) for the 2015/16 year maize production was considered in this study. In fact, a pesticide has relationship with the output of maize production. In the circle of life, maize regularly attacked by some kind of pests. These pest incidences may have negative impacts on both the quality and the yield of the products. But when overdose happens it can lead to low yield or total crop failure. Therefore, application of herbicide was increase the level of production. Therefore, the efficiency level of the smallholder farmer was positive (Kifle, 2014; Ruth, 2011; Bekele, 2013).

3.4.2. Definition of inefficiency variables and hypothesis

The following variables were expected to determine maize technical inefficiency in the study area. Thus, based on theoretical backgrounds and empirical evidences the following socioeconomic, institutional and agro-ecological characteristics of smallholder farmers were hypothesized to explain efficiency differences observed among smallholder farmers:

Educational level of smallholder farmer (Educ): This variable was measured in the number of years of formal schooling of the smallholder farmers. Smallholder farmers were expected to acquire the ability of better management through education and can be used as a proxy variable for managerial ability. Smallholder farmers who attended some level of education were expected to be more efficient, presumably due to their enhanced ability to acquire technical knowledge, which makes them closer to the frontier. It would makes smallholder farmers to be aware of new technologies and farming practices that help to increase yield. It assists them to get the opportunity to process and use updated agricultural information from various sources to increase output through efficient input use. Education was found to relate positively to technical efficiency (Getachew and Bamlak, 2014; Agerie, 2013; Shumet, 2011; Beckhman *et al.,* 2010). Therefore, the level of education attainment of the smallholder farmer was expected to have positive effect on the level of technical efficiency.

Age of smallholder farmer (Age): The continuous variable, age of the smallholder farmer measured in number of years is used as a proxy measure to indicate the general farming experience, of the sample smallholder farmers. It was hypothesized that as the age of the smallholder farmer increases, the smallholder farmer becomes more skillful in the method of production and optimal resource allocation. However, after certain age limit as smallholder farmers get older and older they start to be more conservative and his managerial ability is

expected to decrease as well as less willing to adopt technologies as a result of which their technical efficiency decline. If this hypothesis is true it can be concluded that middle age farmers are more efficient than others. As an instance, age was found to be related positively with technical efficiency in (Kifle, 2014; Getachew and Bamlak, 2014) while it was found to be related negatively with technical efficiency by (Shumet, 2011). Therefore, age was hypothesized to have either positive or negative effect on efficiency of smallholder farmers.

Family size (Famsiz): This is a continuous variable representing the total number smallholder farmer members working on farm. This variable was measured in Man day equivalent. This is to see the effects of family size (number) not only related to labor but also in terms of dependency burden of family members. Family is an important source of labor supply in rural areas. It is expected that smallholder farmers with large family members have better advantage of being able to use labor resources at the right time and also supplementary and complementary effect through income generation by engagement of other activities like off-farm income, particularly during peak cultivation periods. Furthermore, family size could have positive effect in raising the smallholder farmers' production efficiency, if actually the members were in the working force. However, other scholars argued that in the reverse of the former, with large family members have share of resources in the form of consumption, education and other expenditures. Thus, the more family members in a given smallholder farmers were the less efficient. In this study, the number of persons of smallholder farmer administers to manage is considered as family members, regardless of blood relationship. Earlier empirical studies also indicated conflicting results. For instance in some studies (Kifle, 2014; Abba, 2012; Shumet, 2011) family size was found to be positively related with technical efficiency while it was found to be related negatively with technical efficiency in the work reported by (Hassen *et al.,* 2012). Therefore, given labor is main input in the production of maize, it was hypothesized to influence efficiency either positively or negatively.

Farm size (FrmSz): This refers to the total area of cultivated land (own, shared or rented in) that was smallholder farmers managed during 2015/16 production season. This is a continuous variable and measured in ha. It is expected to determine the efficiency differential of smallholder farmers in the study area. It is important to evaluate whether relatively large smallholder farmers were more efficient or not than small ones. As the farm size increases, the manageability may decrease. On the other hand, as the farm size increases, the technical efficiency of the smallholder farmer would be increased. This is because as the farm size of a

smallholder farmer increases, it could enable him/her to enjoy the economies of scale. In the previous studies different results were obtained. For instance, cultivated land was found to be related positively with technical efficiency in (Kifle, 2014; Getachew and Bamlak, 2014; Wondimagegn, 2010; Bekele, 2013) while it was found to be related negatively with technical efficiency by (Geta *et al.,* 2013; Hassen *et al.,* 2012). Therefore, it was hypothesized that either positive or negative effect on technical efficiency.

Slope of maize plot (Slope): This refers the relative steepness of the smallholder farmer's maize plot. It is measured as a dummy variable and the index for the slope of the land plot was constructed based on the respondents' judgments on whether the slope of their maize plot that takes a value of 1 if slope of maize plot is steep and 0 otherwise. Slope of the maize land may affect level of production. For instance steep plots were usually subject to water erosion. As a result, they were likely to be of lower productivity. Since steep plots were vulnerable to erosion damage and they were likely infertile compared to plain plots, slopes of plot were found to be related negatively to technical efficiency (Kifle, 2014; Ruth, 2011; Alemayehu, 2010; Wondimagegn, 2010). It was hypothesized to determine technical efficiency negatively.

Livestock holdig (TLU): It is a continuous variable measured in tropical livestock units (TLU). This variable enters the inefficiency model as a proxy variable for the wealth of the farmers. Theoretically, livestock can support crop production in many ways: cash from livestock sale can improve crop production, supply draft power for many farming-related activities, and they also produce manure that could be used to maintain soil fertility. It also serves as shock absorber to an unexpected hazard in crop failure to buy improved agricultural technologies such as seed, pesticides and the main sources of animal labor in crop production. In this case they would have complementary relationship with crop production implying positive relationship with efficiency. However, livestock production activities can exhibit competitive relationship if both are competing for the same resources. It may compete with maize production for different resources such as land, labor and management. In this case it can be argued that size of livestock have negative association with efficiency. Therefore, it is difficult to hypothesize a priori the effect of livestock holding on efficiency. Earlier studies also indicated conflicting results. For instance, in some empirical studies (Getahun, 2014; Wondimu, 2013; Hassen *et al.,* 2012) livestock holding was found to be positively related with technical efficiency while it was found to be related negatively with technical efficiency

in the work reported by (Shumet, 2011; Bekele, 2013; Endrias *et al.,* 2013;). Therefore, it was hypothesized to be either positive or negative.

Off-farm income (Offarinc): is a dummy variable and measured as 1 if the smallholder farmer was involved in off-farm activities and 0 otherwise. Being involved in off-farm activities may have a systematic effect on the production efficiency of smallholder farmers. The effect on the production of smallholder farmer being involved in off farm activities may have two effects. First, if smallholder farmer spends more time on off-farm activities relative to farm activities; this may negatively affect agricultural activities in terms of time and labor. This is because smallholder farmers may spend more of their time to off-farm activities and thus may lag in agricultural activities. Second, income generated from off-farm activities may be used to acquire purchased necessary inputs timely and hence positively complement farm activities and may be used as extra cash to buy agricultural inputs and also be a supplement for home use. As a result, off-farm income was found to be related positively with technical efficiency in (Getachew and Bamlak, 2014; Wassie, (2012); Alemayehu, 2010) while it was found to be related negatively with technical efficiency by (Teklemariam, 2014; Kifle, 2014; Hassen *et al.,* 2012; Shumet, 2011). Therefore, it was hypothesized that smallholder farmer engaged in off-farm activities to be either positive or negative effect on technical efficiency.

Improved seed Variety (SedVar): It is the usage of both improved maize variety seed and home produced or local seeds. This is a dummy variable indicating 1 if farmers used improved maize seed variety and 0 otherwise. Hence, it was hypothesized that the improved seeds variety can have positive influence on technical efficiency (Kifle, 2014; Endrias *et al.,* 2013; Geta *et al.,* 2013; Hassen *et al.,* 2012).

Access to credit (Credit): This is a dummy variable indicating 1 if a farmer received and used credit in maize production and 0 otherwise. It was used to capture the effect of credit on the production efficiency level of smallholder maize producer farmers. The availability of credit was loosen the constraints of production; therefore facilitating the acquisition of inputs on a timely basis and hence it is supposed to increase the level of efficiency of the smallholder farmers. Farmers who receive credit was assumed to overcome liquidity constraints, purchase more agricultural production inputs or a new technological package such as high yielding seeds since this can be regarded as access to funds (Bekele, 2013; Shumet, 2011; Biforin *et al.,* 2010). Therefore, since access for credit is an important source

of financing the agricultural activities of smallholder farmers, it was hypothesized that smallholder farmers who have accessibility of credit were more efficient than others.

Fragmentation of maize plot (Fragmt): This refers to fragmented number of maize plots that the farmer has managed during the 2015/16 production season. Plots in the area were highly fragmented and scattered over many places that would make difficult to perform farming activities on time and effectively. For smallholder farmers, who used mainly labor for field management, the movement from one field to the other may reduce their efficient utilization of the resources. Increased maize plot fragmentation leads to decrease efficiency by creating shortage of family labor, costing time and other resources that should have been available at the same time (Kifle, 2014; Getachew and Bamlak, 2014; Beckhman *et al.,* 2010). Hence, the study hypothesized that those smallholder farmers with more number of maize plots were less efficient compared to those who have less number of maize plots.

Ownership of maize plot (Ownshp): This is a dummy variable, which would take a value of 1 if maize plot was his own or hired and 0 if maize plot was sharecropped. Smallholder farmers are expected to give priority, especially during peak periods of farming like weeding, to their own plot as they would acquire the whole output that would be obtained from the land. Therefore, it was hypothesized that smallholder farmers tend to be more efficient in managing those lands that were owned and hired than sharecropped lands (Kifle, 2014; Shumet, 2011; Wondimagegn, 2010).

3.5. Data Analysis Methods

Descriptive and inferential statistics along with econometric models was used to analyze the data. Descriptive statistics such as mean, standard deviation, frequency and percentage was employed to analyze the data collected on socio-economic, institutional and agro-ecological characteristics of the sample smallholder farmers while inferential statistics such as t-test and chi-square (^{2}) tests was used to undertake statistical tests on different continuous and categorical data, respectively.

The econometric analyses follow the following processes. For the econometric analysis in the first step, the data was checked for regression model assumption including outliers, multi-co linearity and model specification test. Finally, the data was analyzed using stochastic frontier approach by single stage estimation using FRONTIER Version 4.1 (Coelli and Battese,

2006). The model was estimated parameters of production frontier, level of efficiency, and significance level of the different variables in the determination of inefficiency of smallholder farmers.

3.5.1. Efficiency estimation

Agricultural production is inherent to variability due to random shocks such as drought, weather, pest infection, fires, diseases (rusts). Furthermore, because of many farmers were smallholders in whose farm operations were managed by family members, keeping accurate records is not always a priority. Thus, much available on production were likely to be subjected to measurement errors (Beckhman *et al.,* 2010). Due to these errors and random shocks (white noise) which makes variation in output the stochastic production frontier was used for its key features that the disturbance term is composed of two parts, a symmetric and a one sided component. The symmetric component captures the random effect outside of the control of the decision maker including the statistical noise contained in every empirical relationship particularly those based on cross- sectional household survey data. The one sided component captures deviations from the frontier due to inefficiency.

Therefore, the general stochastic frontier model developed independently by Aigner *et al.,* (1977) and Meeusen, (1977) in which an additional random error, vi, is added to the non-negative random variable μ_i, the SFP function model can be defined as follows:

$$\ln Y_i = \beta_0 + \ln \sum_{j=1}^{n} \beta_i X_{ij} + \ln \sum_{k=1}^{m} \alpha_k Z_{ik} + \mathrm{Exp} \quad \quad (14)$$

ln-denotes the natural logarithm; i represents the ith maize producer smallholder farmer; n represents the number of inputs used; m represents the number of explanatory variables used in the model; Y_i -represents yield of maize output of the ith maize producer smallholder farmer; X_{ij} -refers to j^{th} farm input variables used for maize crop produced on i^{th} plot and similarly Z_{ik} denotes k^{th} inefficiency explanatory variables; ß and stands for the vector of unknown parameters to be estimated; $e_i= v_i-u_i$ which is the residual random term composed of two elements v_i and u_i

The v_i is a symmetric component/ disturbance error term and permits a random variation in output due to factors such as weather, omitted variables and other exogenous shocks. The v_is

were assumed to be independently and identically distributed N (0, σ^2_v) and intended to capture events beyond the control of farmers, independent of u_i.

The other component, u_is, is non-negative random variable and reflects the technical inefficiency relative to the stochastic frontier. The u_is were assumed to be independently and identically distributed as half normal, $u \sim |N (0, \sigma^2_v)|$.

The parameters , $\sigma^2 = \sigma^2_v + \sigma^2_u$ and $\gamma = \sigma^2_u / \sigma^2$ of the above stochastic production function can be estimated using maximum likelihood method, which is consistent and asymptotically efficient (Aigner *et al.,* 1977).

One of the serious problems with the identification of variables to be included in the model is the existence of multi-co linearity among the explanatory (independent) variables. There are different methods, which enable us to see whether or not there is serious multi-co linearity problem. Variance Inflation Factor (VIF) used for the continuous variables and contingency coefficient for the discrete variables. Hence, before using the variables for analysis, VIF was calculated to see if there is severe problem of multi-co linearity. The test was carried out using the STATA version 12 when the regression coefficients were computed. VIF indicates the level of variance that has been inflated to the condition where the variable is not linearly related with other variables (Wondimu, 2013). As a result, continuous variables selected for estimation were checked for the problem of multi-co linearity using Variance Inflation Factor (VIF). According to Gujarati, 2004, value of VIF more than 10 was usually considered as an indicator of serious multi-co linearity. VIF is defined as:

$$VIF(X_i) = \left[\frac{1}{1-R^2_i}\right] \tag{15}$$

Where: X_i = the ith explanatory variable regressed on the other explanatory variables.
R^2_i = is the coefficient of determination when one explanatory variable is regressed against the other explanatory variables used in the model.

Regarding the categorical variables, contingency coefficient, which is a chi-square (χ^2) based measure of association, was employed to check for the presence of multi-co linearity. A contingency coefficient value of 0.75 and above (i.e. 0.75) indicates the existence of a stronger relationship between the variables. The contingency coefficient for the discrete variables entered in to the inefficiency model is given as:

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$$C = \sqrt{\frac{x^2}{n+x^2}}$$ (16)

Where: C = Contingency Coefficient

^{2} = Chi-squwere test and n=total sample size

There were different functional forms to represent the production frontier. The study used the stochastic frontier functional approach, which requires the priori specification of the production function to estimate the level of technical efficiency. The two commonly used functional forms in most empirical studies of agricultural production analysis were Cobb-Douglas and Trans-log, each having their merits and demerits. Both models overwhelmingly dominate the applications literature in stochastic frontier and econometric inefficiency estimation (Coelli and Battese, 2006). Some researchers argue that Cobb-Douglas functional form has advantages over the other functional forms in that it provides a comparison between adequate fit of the data and computational feasibility. It is also convenient in interpreting elasticity of production and it is very parsimonious with respect to degrees of freedom. So nowadays, it is widely used in the frontier production function studies (Getachew and Bamlak, 2014). But it has also some limitations. The disadvantage of the Cobb-Douglas functional form is that it imposes strong assumptions on the nature of the farm technology (i.e it assumes constant elasticity over the input-output curve and unitary elasticity of factor substitution).

On the other hand there are cases where the trans-log model fits better to the data if the cross product effects of the independent variables have significant role in the process of maximum likelihood estimation of the parameters of the model. This functional form allows flexibility in providing approximation to any twice differentiable function and for its ability to capture interaction among inputs (Wondimagegn, 2010). But the problem of multi-co linearity is a serious problem in trans-log production function. As a result, taking the advantages and disadvantages of both functional forms into consideration the appropriate functional form that better fit the data was selected after testing the null hypotheses using the generalized likelihood ratio test. Thus, Cobb-Douglas frontier function was specified as follows:

$$\ln Y = \alpha_0 + \sum_{j=1}^{n} \alpha_j \ln X_{ji} + V_i - U_i$$ (17)

Where for plot ith plot, Y is the total quantity or value of maize produced, X is the quantity or value of input j used in the production process including oxen power, human labor, maize

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plot, amount of seed and amount of fertilizer; V_j is the two-sided error term and U_j is the one-sided error term (technical inefficiency effects).

The second specification was the Trans log model, which is given by stochastic frontier Production

$$lnY = \alpha_0 + \sum_{j=1}^{n} \alpha_j \, lnX_{ji} + \frac{1}{2}\sum_{j=1}^{n}\sum_{j=1}^{n} \alpha_{ji} \ln X_j \ln X_i + V_i - U_i \qquad (18)$$

Where the entire variable are as previously defined

The technical efficiency effects model (Coelli and Battese, 2006) in which both the stochastic frontier and factors affecting inefficiency are estimated simultaneously is specified as:

$$\ln(OUTP) = \beta_0 + \beta_1 \ln(AREA) + \beta_2 \ln(LAB) + \beta_3 \ln(SEED) + \beta_4 \ln(UREA) +$$
$$\beta_5 \ln(DAP) + \beta_6 \ln(OXPW) + \beta_7 \ln(HERB) + v_i - [\delta_0 + \delta_1 Educ + \delta_2 Age + \delta_3 Famsiz +$$
$$\delta_4 FrmSz + \delta_5 Slope + \delta_6 TLU + \delta_7 Offarinc + \delta_8 SeedVar + \delta_9 Credit + \delta_{10} Fragmt +$$
$$\delta_{11} Ownshp + w_i] \qquad\qquad (19)$$

Where: **ln**-the natural logarithm

OUTP - is the total output of maize obtained from the ith plot measured in quintal;

AREA - is the maize plot size of the ith plot measured in hectare;

LAB - is the amount of pre-harvest labor for plowing, weeding and preparing land on the ith plot measured in man day equivalent;

SEED - is the amount of maize seed used on the ith plot measured in kg;

UREA/DAP - is the amount of UREA/DAP fertilizer used on the ith plot measured in kg;

OXPW - the amount of draught power used for different farming activities on the ith plot measured in oxen day;

HERB - is the amount of herbicide used for maize production on the ith plot measured in litter.

$_i$- vector of unknown parameters to be estimated

Where the inefficiency variables used in the above model were defined as follows:

Educ - is the education level of the smallholder farmer measured in continuous years of schooling;

Age - age is defined as the age of the smallholder farmer in years;

Famsiz -This represents the total number smallholder farmer members working on farm.

FrmSz- is the total land size operated by the smallholder farmer during the production year including his owned land, rented in and rented out lands used for cultivation of different crops measured in ha,

Slope - is a maize plot slope of as a dummy variable which would take a value of 1 if the plot is plain and 0 otherwise;

TLU - is the total number of livestock in terms of Tropical Livestock Unit (TLU);

Offainc- It is measured as a dummy variable that takes a value of 1 if the smallholder farmer participated in off-farm activity and 0, otherwise.

SeedVar- It is measured as a dummy variable that takes a value of 1 if the smallholder farmer has used improve seed and 0, otherwise.

Credit - is a dummy variable which represents whether the smallholder farmer has obtained credit or not during production season;

Fragmt - is the number of maize plots and it is considered as a dummy variable, which would take a value of 1 if smallholder farmer has one and two and 0 if smallholder farmer has, more than three;

Ownshp- it is considered as a dummy variable, which would take a value of 1 if the smallholder farmer land is his own or hired and 0 if the land is sharecropped.

$_i$- Parameter vector associated with inefficiency effect to be estimated and $\mathbf{w_i}$- Error term.

The one-stage estimation procedure of the inefficiency effects model together with the production frontier function was used in the study. The two-stage procedure produces inconsistency in the assumption (Coelli and Battese, 2006). Moreover one-stage procedure is the most commonly used method in the analysis of technical efficiency. Thus one-stage procedure was selected for this study.

The maximum likelihood estimates of the parameters of the frontier model were estimated, such that the variance parameters were expressed in terms of the parameterization

$$\frac{2}{s} = \ ^2 + \ \frac{2}{v} \text{ and } \ = \frac{2}{\frac{2}{s}} = \frac{\sigma^2}{\frac{2}{s} + \sigma^2} \tag{20}$$

Where: the parameter has a value of between 0 and1. A value of of zero indicates that the deviations from the frontier were entirely due to noise, while a value of one would indicate that all deviations were due to technical inefficiency.

^{2} - is the variance parameter that denotes deviation from the frontier due to inefficiency;

$_v^2$ - is the variance parameter that denotes deviation from the frontier due to noise

$_s{}^2$ - is the variance parameter that denotes the total deviation from the frontier.

The existence of inefficiency can be tested using   parameter and can be interpreted as the percentage of the variation in output that is due to technical inefficiency. The Log-Likelihood ratio was used to test the null hypothesis that the inefficiency component of total error term is equal to zero (= 0) against the alternate hypothesis that the inefficiency component is greater than zero (> 0). Thus, the log likelihood ratio will be calculated and compared with the critical value of ^{2} with one degree of freedom at 5% level of significance. Likewise the significance of ^{2} indicate whether the conventional average production function adequately represent the data or not.

The validity of the models used for the analysis and hypothesis test is investigated using the general Likelihood ratio test. Following Beckhman *et al.,* (2010) the most appropriate functional form that better fits the sample data is selected after testing the two functional forms (Cobb-Douglas or Trans-log) using the Log- likelihood ratio test (LR) result: Generalized Likelihood ratio computation was defined as;

$$LR = -2\ln[L(H_o)/L(H_1)]$$

$$LR = -2[\ln L(H_o) - \ln L(H_1)] \tag{21}$$

Where: LR (Log likelihood ratio), LH_o (Value of log likelihood of null hypothesis (Log-likelihood value of Cobb-Douglas)) and LH_1 (Value of log likelihood of alternate hypothesis (Log-likelihood value of trans-log))

Then this value was compared with the upper 5% point for the ^{2} distribution and decision was made based on that result. The null hypothesis was found to be rejected when LR (calculated ^{2}m*) > tabulated ^{2} m*.

m*=degree of freedom= number of restrictions= number of estimated inputs and inefficiency variables in the current model (alternate hypothesis) minus number of estimated inputs and inefficiency variables in the preceding model (null hypothesis).

In the prediction of firm level technical efficiencies, Coelli and Battese, (2006) pointed out that the best predictor of exp ($-\mu_i$) is obtained by:

$$E[\exp(-\mu_i)/e_i] = \frac{1-\phi(\sigma_A + \gamma e_{i/\sigma_A})}{1-\phi(\gamma e_i/\sigma_A)} \exp(\gamma e_i + \sigma^2/2) \qquad (22)$$

Where $\sigma_A = \sqrt{\gamma(1-\gamma)\sigma_s^2}$; $e_i = \ln(y_i) - x_i\beta$; $\phi(.)$ is the density function of a standard normal random variables.

The above Coelli and Battese, (2006) models, presented in Equation (19) to (22), can be estimated using the computer program, FRONTIER version 4.1, written by Abba, (2012). FRONTIER 4.1 is a single purpose package specifically designed for the estimation of stochastic production frontiers and has the advantage of specifying distributional assumption for the estimation of the inefficiency terms. In addition FRONTIER is able to accommodate a wider range of assumptions about the error distribution term such as half-normal and truncated normal distributions.

3.5.2. Marginal effects for inefficiency model

The estimated parameters on the inefficiency model coefficients do not directly give the marginal effects of the associated independent variables on the dependent variable. But their signs show only the direction of the effects that the variables had on inefficiency levels (where a negative parameter estimate shows that the variable reduces technical inefficiency). In contrast, quantification of the marginal effect was indicates the effect of inefficiency variables on technical efficiency level. According to Coelli and Battese, (2006), quantification of the marginal effects of inefficiency variables on technical efficiency was done by partial differentiation of the technical efficiency predictor with respect to each variable in the inefficiency function. The marginal effects represented by the equations below were calculated by the STATA command mfx, which was complemented by specific options that allowed the estimation of marginal effects of change in explanatory variables. A useful decomposition of marginal effects of an explanatory variable for y (dependent variable) as follows;

$$E(y) = \frac{\partial E(y/x)}{\partial x_k} = \Phi\left(\frac{x_i\beta}{\sigma}\right)\beta_x \qquad (23)$$

where, X_i are explanatory variables; $\delta = \frac{x_i\beta}{\sigma}$ is the Z-score for the area under normal curve; β_x is a vector of C-D maximum likelihood estimates; σ is the standard error of the error term, and $^-$ represents cumulative density functions of the standard normal distribution.

The expression $\Phi\left(\frac{x_i\beta}{\sigma}\right)$ which is called the scale factor for effects is simply the estimated probability of observation at the values of x_i or it is the sample proportion of observations in

the total observation. In this study, the Marginal effect of explanatory variables represented as $\left(\frac{\partial y}{\partial x}\right)$ on the expected value for inefficiency scores (dependent variable) was considered.

Table 4. Summary of input and technical inefficiency variables and their expected signs

Variable	Coefficients	Measurement	Expected sign
Input Variables			
Area	1	Hectare	+
Labor	2	MDE	+
Seed	3	Kilogram	+
Urea	4	Kilogram	+
DAP	5	Kilogram	+
Oxen power	6	ODE	+
Herbicide	7	Litter	+
Inefficiency Variables			
Education level	1	1 if HH head is literate, 0 otherwise	+
Age	2	Number of years	+/-
Family size	3	Numbers	+/-
Farm size	4	Hectare	+/-
Slope	5	1 if maize plot farm is steep, 0 otherwise	-
Livestock	6	TLU	+/-
Off-farm income	7	1 if involved off-farm activities, 0 otherwise	+/-
Seed variety	8	1 if Maize seed variety used, 0 otherwise	+
Credit	9	1 if there is access, 0 otherwise	+
Fragmentation of land	10	1 if more than one plot, 0 otherwise	-
Ownership of land	11	1 if the land is shared , 0 otherwise	+

Source: Different previous researches, (2015/16)

4. RESULTS AND DISCUSSION

This chapter divided into two sections. The first section deals with the results of descriptive analysis pertaining to socio-economics, demographic characteristics and various agricultural activities undertaken by sample smallholder farmers. In the second section, the econometric results related to level of technical efficiencies and determinants of technical efficiency in maize production from the stochastic frontier function models presented and discussed.

4.1. Descriptive Statistics

The descriptive statistics presented in this section was comprised of various sub section. The discussion was categorized as demographic and socio economic characteristics; resource basis; crop production and input utilization and institutional characteristics of smallholder farmers in the study area were discussed briefly. This help to draw a general picture about the study area and sampled smallholder farmers.

4.1.1. Demographic and socio economic characteristics of smallholder farmers

Under this part, family size, age structure, level of education, sex and marital status of smallholder farmers were discussed as follows.

Smallholder farmer family size and its structure has decisive role in the farm economy. It determines the amount of resource availability and economic status of farm family. An attempt was made to study smallholder farmer family size and its structure. The survey result (Table 5) showed that average smallholder farmer family size of sample smallholder farmer was 6.42 persons, which was higher than the rural population national average of 3.8 persons (CSA, 2011). The largest smallholder farmer family size was being 11 persons while the smallest size was 3 persons per smallholder farmer (including the household head).

Age of smallholder farmer is important to study such a long period phenomenon, related with the change in farm size and extent of subdivision. All these contribute in determination of individual farm efficiency. The study result (Table 5) showed that on average the age of the smallholder farmer was 46.65 years with standard deviation of 12.14.

Level of education upgrades the ability and changes the attitude of person in a given society. Educated smallholder farmers were expected to adopt new agricultural technologies and had

better managerial skill. An attempt was made to assess the level educational status of the sample smallholder farmers who had informal and formal education. The study indicated that 64.2% of the sample smallholder farmers were illiterate (cannot write and read). In contrast, 35.8% were able to read and write. In terms of sex, 90.8% of the respondents were males and the remaining were females. Regarding marital status of the smallholder farmers, 88.3% were married, while 0.8%, 8.3% and 2.5% of the smallholder farmers were single, widowed and divorced respectively (Table 5).

Table 5. Demographic characteristics of the sample smallholder farmers

Characteristics		Number	%
Educational level of smallholder farmers			
	Illiterate	77	64.2
	literate	43	35.8
Sex of smallholder farmers			
	Male	109	90.8
	Female	11	9.2
Marital status of smallholder farmers			
	Married	106	88.3
	Single	1	0.8
	Widowed	10	8.3
	Divorced	3	2.5
Characteristic	**Unit**	**Mean**	**Std. Dev.**
Family size members	Numbers	6.42	1.75
Age of smallholder farmers	Years	46.65	12.14

Source: Computed from Field Survey Data, 2015/16

4.1.2. Resource basis

Under this part, land holding, livestock and off-farm activities which were the major resources in the rural area affecting smallholder farmer's decision in maize production were discussed as follows.

4.1.2.1. Land holding

Land is the indispensible livelihood means or resource base for the rural community and plays typical role in farming. The size of land allocated for maize production has an influence on technical efficiency and the total amount of maize yield. An attempt was made to study the size of cultivated area on sample smallholder farmers of Fogera district. Farmland in the study area is rather scarce. The survey indicated that the average landholding of own land and sharecropping were 1.39ha and 0.77ha, respectively (Table 6). This holding size is even less by 16.35% than the national average landholding of 1.24ha (CSA, 2006).This coupled with

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poor fertility status of the soil and large family sizes of smallholder farmers in the area aggravate the dearth of farmland. To mitigate the challenge of land shortage, young farmers usually shared land with their parents and relatives during marriage or obtained land use access through sharecropping. In the study area, sharecropping was the second important means of acquiring land for cultivation next to own lands. Smallholder farmers preferred sharecropping than renting due to high price. Sharecropping agreements were mostly effected in two options in maize production: annual agreement or agreement exceeding a year. Under the former condition, the owner provides the cultivable land to the operator only for one year, and the owner shares fertilizer and seed costs with the operator equally. Whereas in the later case the land is given to the operator for 2-5 years in which case all costs was covered by the operators. Generally, the choice of the option and the decision of the contract period sharecropping, highly depend on the willingness of the owner, as both parties believe longer period agreements will favor the land operator was the criteria. Furthermore, the average cultivable farm land size and grazing land were 1.77ha and 0.26ha, respectively. From average total farm land size 2.04ha, smallholder farmers allocated to maize production on average 0.48ha (Table 6). The difference in land holding size among smallholder farmers expected to be explained the difference in the level of efficiency.

Table 6. Land allocation of the Smallholder farmers in 2015/16 production year

Land size in Ha	Mean	Std. Deviation	Minimum	Maximum
Own land	1.39	0.50	0.38	2.5
Sharecropping land	0.77	0.47	0.25	3.8
Maize farm plot	0.48	0.15	0.25	1.5
Cultivable farm land	1.77	0.55	0.50	4.8
Grazing land	0.26	0.13	0.13	0.8
Total farm land	**2.04**	**0.59**	**0.75**	**5.3**

Source: Computed from Field Survey Data, 2015/16

Note: Cases by land sources add up more than 120 because of land acquisition of a household from more than one source.

4.1.2.2. Livestock holding and use

Under this part, number of livestock and draught power utilization by smallholder farmers were discussed as follows.

Number of livestock: Livestock have diverse functions for the livelihood of smallholder farmers in mixed farming system. They provide food in the form of meat, milk, and non-food items such as draught power and manure as inputs into crop production. In addition, they were source of cash income and act as a store of wealth and play a determinant role in social status within the community and buffering risk. The types of livestock kept by smallholder farmers' were cattle, sheep, goats and poultry (Appendix Table 7).

Table 7.Livestock holding and distribution of oxen of the Smallholder farmers

Livestock	Mean	Std. Deviation	Minimum	Maximum
TLU	9.16	3.69	0	23.70
No. of oxen	**Number of Smallholder farmer**		**%**	
1	21		17.5	
2	57		47.5	
more than 3	42		35	

Source: Computed from Field Survey Data, 2015/16

Considering the number of livestock holding by sample smallholder farmers in terms of tropical livestock unit (TLU), in the study area of the average livestock holding per sample smallholder farmer was found to be 9.16 TLU with standard deviation of 3.69 TLU. The maximum livestock ownership in terms of TLU was 23.7. This shows that there is a high population of livestock as well as a wide variability in terms of livestock ownership among the smallholder farmers (Table 7).

Draught power: In the study area, oxen power was found as an important factor of production. Oxen power utilization by sample smallholder farmers was computed by assuming working of 8 hours by pair of oxen per day. Shortage of draught power limits the area that can be cultivated. Shortage of oxen power leads to poor land preparation and delayed completion of the operation. Poor land preparation leads to poor plant establishment, heavy weed infestation and low yields. The number of draught animals determines the amount of land that can be cropped, total crop production and yield. Larger holding of oxen permit a greater area of land to be cultivated. Given the above fact, the survey indicated that 17.5% of the sample smallholder farmers owned one ox while 47.5% of them owned one pair of oxen. On the other hand, 35% of the sample smallholder farmers owned more than three

oxen (Table 7). Owners of a single ox in the area plough their land through a system called *mekenaajo[1]*.

Furthermore, in the three sample kebeles, smallholder farmers on average ploughed their land three to five times for production of maize. Usually the land preparation started from the first commencement of rain and they continued plowing each month until sowing of the maize crop but it depends on farmer's strength. Weed infestation was found to be a problem in the area due to the high rain fall from the month of June to August. It was also observed that the sample smallholder farmers in the study area were given more emphasis to plowing as compared to weeding which is the major challenge for improving productivity.

4.1.2.3. Off-farm activities

In addition to farm sector, there is engagement on different off-farm activities by the smallholder farmers in the study area during the production season of 2015/16. The detail data on this respect indicates 29 smallholder farmers (24.2%) engaged in off-farm activities either by smallholder farmer or through the family members such as labor work, pension payment, remittance, wage and rent from asset. Furthermore, 91 sample smallholder farmers (75.8 %) were engaged in agricultural activities (Figure 7). In other words, they were not full time farm workers participated on maize production development in the study area. Hence, the impact (i.e. negatively) of off-farm activities on maize production could be considerable.

Figure 7: Smallholder farmer's response on off-farm activities

Source: Computed from Field Survey Data, 2015/16

As shown in Table 8, the main sources of off-farm income were labor work, rent from asset, remittance, pension payment and wage. Smallholder farmers of 5.8% were generated off-

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[1] Mekenajo is a traditional oxen exchange arrangement that requires making an agreement with other single ox owner for plowing their land on rotational basis (commonly in an interval of one day).

farm income from labor work and rent from asset. Smallholder farmers of 4.2% were also generated from remittance. Smallholder farmers of 3.3% of respondents were engaged in wage and pension payment while the remaining 1.7% was engaged in other off-farm activity. In the study area, 24.2% of the sample smallholder farmers were engaged in off-farm activities in order to augment their financial shortage of production such as fertilizer as well as improved maize seeds and to cover other smallholder farmer expenditures like children education expense.

Table 8. Main sources of off-farm income and responses of the smallholder farmers

Types of off-farm activities	Number	%
labor work	7	5.8
pension payment	4	3.3
remittance	5	4.2
wage	4	3.3
rent from asset	7	5.8
other	2	1.7
Total	**29**	**24.2**

Source: Computed from Field Survey Data, 2015/16

4.1.3. Crop production and input utilization by sample smallholder farmer

Under this part, cropping system, soil fertility management, maize plots distance from the residence and maize plot fragmentation, level of productivity and input utilization in maize production of smallholder farmers were discussed as follows.

4.1.3.1. Cropping system

The dominant farming system of the District is mixed crop-livestock. Crops and cropping activities were essentially determined by crop calendar which mainly depend on rainfall pattern and distribution. Maize, teff, barley, finger millet, rice, pulses such as beans, peas and Niger seed from oil crops were commonly grown in the area. Among cereals, maize was the dominant crop in terms of area and number of growers. There were no as such, perennial as well as vegetable cropping except some backyard efforts by few smallholder farmers where limited production of crops like eucalyptus, hop, tomato, potato, and cabbage were undertaken. Inputs of land, oxen power for plowing, labor and mostly local seeds (except a few maize producers) were the locally originating inputs of the cropping system in the area. Commercial fertilizer was applied only for maize, teff and finger millet crops in the 2015/16 cropping season. Other chemical inputs such as herbicides and pesticide were used to less

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extent for maize, chickpea and vetch crop production system. Crop production in the area generally seems diversified. Smallholder farmers told that deteriorating soil fertility, small average land holding, little use of improved inputs, erratic rainfall, drought, limited access to credit, market and input technologies, poor infrastructure, delayed supply of fertilize to meet the time-sensitive needs and the different production calamities or natural risks prevailing in the area were the major maize production problems.

4.1.3.2. Soil fertility management

In tackling the land fertility problems, different measures that have an immediate and long run effects were undertaken. The efforts include soil and water conservation such as terracing, use of commercial fertilizer, compost, manure, and crop rotation. The tendency of chemical fertilizer application in the area was very low due to the shortage supply. Smallholder farmers apply DAP and Urea fertilizers only for maize and partially for teff and finger millet crops. In 2015/16 cropping season all of the 57.125 ha maize plots were using DAP and Urea fertilizer. The sample smallholder farmers mentioned that financial scarcity, lack of adequate credit access, and untimely fertilizer supply as constraints for adequate fertilizer use in maize production.

Compost production and use is currently highly promoted by the government (Table 9). Smallholder farmers explained the problem in this regard, and thus little use of the technology in the area. The cool environment that hinders easy decomposition for compost formation, the undulated terrain, poor infrastructure, shortage of biomass, and fragmented plots make difficult the wider application of the technology. Besides, although shortage of land is a serious problem in the area, occasionally fallowing is also taken as a strategy of fertility replenishment when production of pulses or oil crops in the exhausted land is not found feasible.

Moreover, there were other methods of soil fertility management including crop rotation and soil and water conservation structures practiced in the study area. Particularly, the significance of crop rotation in soil fertility maintenance is highly appreciated in the smallholder farmers cropping plan. Crop rotation practice of the area involves growing leguminous crops every other year after cereals. The importance of legumes and pulses in improving soil fertility is well recognized by the smallholder farmers in the community.

Table 9.Soil fertility management, Maize plots distance from the residence and fragmentation

Characteristics	Number of smallholder farmer	%
Soil fertility		
Fertile	87	72.5
Not fertile	33	27.5
Compost availability		
Yes	93	77.5
No	27	22.5
Slope		
Plain	32	26.7
Steep	88	73.3
Walking time in minutes		
<10	68	56.7
11-20	27	22.5
21-30	9	7.5
Above 30	16	13.3
Maize plot fragmentation		
1	30	25.0
2	77	64.2
Above 3	13	10.8
Total	**120**	**100**

Source: Computed from Field Survey Data, 2015/16

4.1.3.3. Maize plots proximity to homestead and fragmentations

Proximity of maize plots to homestead: Proximity of maize plots to homestead is defined as the distance of the farm from the house of the smallholder farmers in walking minutes. As the plots are farther from the residence, it is more difficult to manage the plots timely (Kifle, 2014). Smallholder farmers whose maize plots were located away from their home not only spend extra time to reach their plots and back to home. In addition, labor that was involved in agricultural operations also would be fatigue by the time it arrives at the maize plot that consequences on the labor efficiency. It implies that any viable plot distance reduction measures would have an effect on improving the technical efficiency of maize producers in the area.

As indicated in Table 9, 56.7% of the smallholder farmers' plots were situated within less than 10 minutes of walking distances and 22.5% were walking 11 to 20 minutes. On the other hand, nearly 13.3% of the smallholder farmers ought to travel more than half hour to find their maize plots while the remaining 7.5% of the smallholder farmers walk between 21 to 30 minutes.

Maize plot fragmentations: The cultivated maize plot area was divided into several parcels. The number of parcels ranged from 1 to 5 with average and standard deviation of 1.88 parcels and 0.63, respectively. Smallholder farmers (64.2%) in the study area owned cultivated land constituting two parcels scattered at different locations. The general distribution of the parcel land was summarized in table 9.

4.1.3.4. Level of productivity and input utilization in maize production

The sample smallholder farmers realized a mean yield of 12.59 qt/ha (Table 10). Sample smallholder farmers were explained the productivity level achieved in the cropping season is lower than their average yield of the good season. Late time moisture stress and untimely fertilizer supply were mentioned to be causes of yield loss for maize in the cropping season. Assessing the productivity loss estimated by these and other similar externalities will have policy relevance. To this end, smallholder farmers were asked how much they could have obtained from their maize plots in the cropping season had there been no hazard or good climatic condition to their maize cultivation.

Furthermore, the two commonly used chemical fertilizers in the production of maize were DAP and Urea. The average amount of DAP and Urea applied by sample smallholder farmers were average 53.96 kg and 38.58 kg per ha, respectively. In general, there was high variation in the application of fertilizers in maize production among the sample smallholder farmers. The average amount of seed applied by sample smallholder farmers were 23.78 kg per ha.

Table 10. Level of productivity and input application in maize production

Item	Mean	Std. Deviation	Minimum	Maximum
Output(Qt/ha)	12.59	5.72	4	38
Oxen Labor (OD/ha)	10.52	3.39	4	20
Human Labor(MD/ha)	12.75	4.10	3.56	21.6
Seed (Kg/ha)	23.78	6.75	12.50	60
Quantity of Dap(Kg/ha)	53.96	23.07	20.00	150
Quantity of Urea (Kg/ha)	38.58	16.14	20.00	100
Area under maize (ha)	0.47	0.15	0.25	1.5

Source: Computed from Field Survey Data, 2015/16

The survey results revealed that on average, human labor days used in the cultivation of maize was 12.75 man days per hectare with the standard deviation of 4.10 (Table 10). Similarly the mean use of oxen labor was 10.52 oxen days per ha with the standard deviation of 3.39 oxen days.

4.1.4. Status of institutional services

4.1.4.1. Credit access

Agricultural credit in the area is limited and formal and informal institutions were the two main sources of credit in the study district. The major sources of informal credit were relatives and local money lenders. Smallholder farmers use such credit to meet family consumption requirements such as food purchases, educational, medical expenses and goes for the purchase of fertilizer, improved seed and small ruminant animal production. However, local money lenders charge very high interest rate while micro financing institutions provided short term credits at a relatively less interest rate. Smallholder farmers and their families were compelled to travel more than 2 hours of a round trip if they have to get credit access from bank.

The Amhara Credit and Saving Institution (ACSI) provide services to smallholder farmers. Smallholder farmers had received credit from this institution to purchase fertilizer, purchase of oxen and to meet social obligations. The sample smallholder farmers reported that about 45.8% of them were received credit from ACSI in 2015/16 production year.
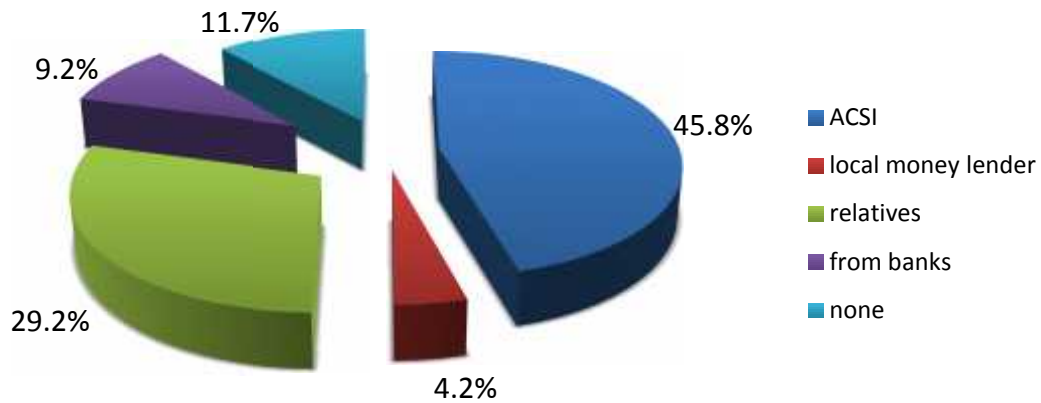
Figure 8: Major sources of credit for the sample smallholder farmers

Source: Computed from Field Survey Data, 2015/16

The survey results (Figure 8) revealed that, 45.8%, 4.2%, 29.2% and 9.2% were preferred as a source of credit from Amhara credit and saving association, local money lenders, relatives and from banks, respectively to meet their various socioeconomic requirements while the remaining 11.7% were not utilized credit.

4.2. Results of Econometric Analysis

In this sub chapter, results of hypotheses test and model robustness, OLS and ML estimates of production functions, efficiency scores, determinants and marginal effects of inefficiency variables were presented and discussed clearly.

4.2.1. Estimation of technical efficiency

The maximum likelihood estimate of the parameters of the stochastic production was estimated using Frontier 4.1 version computer program. Before proceeding to examine the parameter estimates of the production frontier and the factors that affect the inefficiency of maize sample smallholder farmers, there is a need to conduct some tests for variables incorporated under the estimation of stochastic production frontier and investigate the existence of inefficiency effects among maize producers.

Before estimation of technical efficiency and analysis of its determinants, variance inflation factor (VIF) for the continuous variables and contingency coefficient (CC) for the discrete variables were examined to check the problem of serious multi-co linearity. Based on equation 15, all production inputs used were found to be within VIF range of 1.33 to 1.73. This value lies with the acceptable range for the Cobb-Douglas production function estimation (Appendix Table 3). Hence, there is no variable with a VIF value of more than 10. Regarding the categorical variables (equation 16), the variables that were supposed to be related to technical inefficiency level were also tested for multi-co linearity problem and (Appendix Table 4 and 5) results have shown that there was no multi-co linearity problem among variables.

4.2.1.1. Hypothesis testing and model robustness

Before proceeding to examine the parameter estimates of the production frontier and factors that affect the efficiency of the smallholder farmers, the validity of the model used for the analysis was investigated. The Cobb-Douglas and the Trans-log functional forms were the most commonly used stochastic frontier functions in the analysis of technical efficiency in production. As a result, the next step was to check whether the production technology of the sample smallholder farmer is better represented by the Cobb-Douglas production function or the Trans-log production function. To select the appropriate specification, both Cobb-Douglas and Trans-log functional forms were estimated (Appendix Table 7).

The hypothesis was tested using the generalized Likelihood Ratio (LR) statistics, which can be computed from the log likelihood values obtained from estimation of Cobb-Douglas and Trans-log functional specifications.

In summary, the following tests were carried out for testing the functional forms, inefficiency effects and determinants of coefficients for maize farmers in the study areas:

(1) Frontier model specification for the data is Cobb-Douglas production function.

That is H_0: C-D ($_8$ .... $_{35}$=0) is an adequate representation of the production function.

$H1_1$: Trans-log production function is adequate representation of the production function. Here

$_8$ .... $_{35}$ represents Trans-log production function

(2). Distribution assumption (H_0: μ=0)

(3). There is no inefficiency effect that is (H_0= =0)

(4). The coefficients of determinants of inefficiency model equals zero that is

(H_0= $_0$= $_2$.......= $_{11}$=0)

(5) Return to scale (H_0: i=1)

4.2.1.2. Results of the hypotheses test

The formulation and results of different hypotheses (model selection, inefficiency effect) were presented in Table 11. All the hypotheses were tested by using generalized likelihood-ratio (LR).

The first hypothesis related to the appropriateness of the Cobb-Douglas functional form in preference to trans-log model. The computed LR statistic was less than the table value at 5% significance level (LR statistic 26.42< 32.67). The null hypothesis was accepted by indicating that the Cobb-Douglas functional form is a better representation of the data. This showed that the coefficients of the interaction terms and the square specifications of the input variables under the Trans-log specifications were not different from zero. This implies that the Cobb-Douglas functional form adequately represents the data under consideration. Hence, the Cobb-Douglas functional form was used to estimate the technical efficiency of the sample smallholder farmers in the study area.

Table 11. Summary of hypotheses test for parameters of stochastic production function

Hypothesis	df	LH_0	LH_1	Calculated x^2 (LR)	Critical x^2	Decision
1. Production Function is Cobb Douglas H_0 : C-D ($_8\ldots._{35}=0$); H_1 : Trans-log production function	21	1.27	14.48	26.42	32.67	Accepted
2. Distribution assumption (H_0: μ=0)	1	53.75	54.85	2.2	2.71	Accepted
3. There is no inefficiency component (H_0: =0)	1	-27.91	1.27	53.28	3.84	Not accepted
4. The coefficients inefficiency model equals zero ($H_0=_0=_2\ldots\ldots=_{11}=0$)	11	-20.27	1.27	43.08	19.68	Not accepted
5. Return to scale (H_0: $_i=1$)	1	-214.81	1.27	432.16	3.84	Not accepted

Source: Computed from Field Survey Data, 2015/16

The second hypothesis test was conducted for about the distributional assumption of the one sided error term. Given Cobb-Douglas stochastic frontier production function best fits the data, the researcher tests hypothesis whether the technical efficiency levels were better estimated using a half normal (μ=0) or a truncated normal distributional assumption of U_i (μ>0) using FRONTIER VERSION 4.1. Based on equation 21, ln{L(H$_o$)} and ln{L(H$_1$)} are the values of the log-likelihood function under the null (H$_o$) and alternative (H$_1$) hypotheses. The restrictions form the basis of the null hypothesis, with the unrestricted model being the alternative hypothesis. As can be seen from Table 11 above, the results indicated that the half normal distribution was appropriate for the sample smallholder farmers in the study area as the calculated LR value of 2.2 was less than the critical ^{2} value of 2.71 at 5% significance level.

The third hypothesis was tested for the existence of the inefficiency component of the total error term of the stochastic production function. In other words, it was concluded whether the average production function (without considering the non-negative random error term) best fits the data. The difference between the average response function and stochastic production frontier is that the later decomposes the total error into one sided inefficiency parameter and random normal error. If the one sided error term is equal to zero, the stochastic production function model is identical to the average response function indicating that there is no efficiency difference among farmers. This can be tested by comparing the Log-Likelihood values of the OLS with SPF (MLE). Hence, the third hypothesis stated that =0, was not accepted at the 5% level of significance confirming that inefficiencies existed and were indeed stochastic (LR statistic 53.28> 3.84) (Table 11). The coefficient for the parameter could be interpreted in such a way that about 84% of the variability in maize output in the

study area was attributable to technical inefficiency effect, while the remaining about 16 percent variation in output was due to the effect of random noise. This implies that there was a scope for improving output of maize by first identifying those institutional, socioeconomic and farm specific factors causing this variation.

The fourth hypothesis which stated the technical inefficiency effects were not related to the variables specified in the inefficiency effect model. To test this hypothesis likewise, LR (the inefficiency effect) was calculated using the value of the Log-Likelihood function under the stochastic production function model (a model without explanatory variables of inefficiency effects: H_0) and the full frontier model (a model with explanatory variables that were supposed to determine inefficiency of each: H_1). It was also not accepted at the 5% level of significance (LR statistic 43.08 >19.68) (Table 11). Thus the observed inefficiency among the smallholder farmers in Fogera could be attributed to the variables specified in the model which exercised a significant role in explaining the observed inefficiency.

The fifth hypothesis test was conducted to check returns to scale. It can divide the dependent variable output and all independent variables by maize plot size to get constant return model specification. The result of the estimation made under both model specifications, under constant returns to scale and variable returns to scale, shows that the log-likelihood function is equal to -214.81 and 1.27, respectively. Thus, the log likelihood-ratio test is calculated to be 432.16 and when this value is compared to the critical value of 3.84, the null hypothesis that the production system is characterized by constant return to scale was not accepted (Table 11). The estimation result presented in Table 11 shows that the return to scale is equal to 0.94. In this case the return to scale is decreasing returns to scale. Thus, the production structure, given these inputs, is characterized by decreasing returns to scale. As a result, a 1% increase in all the specified production inputs, output increases by 0.94%. Therefore, an increase in all production inputs by 1% will increase maize yield by less than 1%. It can be escaped from stage II of production surface by using their existing resources and technology efficiently in the production process. Therefore, there is still exists opportunities for improving on their current level of technical efficiency and they can obtaining maximum maize output from their given quantity of inputs. This result was consistent with a study by Gbigbi (2011) in Nigeria found returns to scale to be 0.85.

4.2.1.3. Parameter estimates of the SPF model

As indicated in the data analysis of the methodological part, the specified Cobb-Douglas functional form of the stochastic frontier model with half-normal distributional assumption of the error terms is considered to estimate the model or parameters of the model. The parameters were estimated simultaneously with those involved in the model for the inefficiency effects. Table 12 presents the results of both the OLS and ML estimates as well as inefficiency model result. In total twenty parameters were estimated in the stochastic production frontier model including seven in the C-D production frontier model, and eleven explanatory variables were hypothesized to influence the technical efficiency scores while the remaining two being the parameters associated with the distribution of μ_i and v_i. Out of the twenty parameters estimated, eleven were statistically significant. From eleven significant parameters, two were significant at 1% level; eight were significant at 5% level while the remaining one was significant at 10% level of significance. Moreover, the value of log likelihood function for both OLS estimations and the stochastic production function was computed. The Maximum Likelihood estimates of the parameter of SPF functions together with the inefficiency effects model were presented in Table 12.

Table 12. Maximum likelihood, OLS estimate and technical inefficiency determinants for Cobb-Douglas production function

Variable	Parameter	Ordinary least squares		Maximum likelihood estimate	
		Coefficient	t-ratio	Coefficient	t-ratio
Constant		-0.401	-0.8817	0.435	1.455
LnArea		0.365	3.0561***	0.230	2.196**
LnLabor		0.018	0.7476	0.017	0.944
LnSeed		-0.789	- 1.7041**	-0.962	- 2.257**
LnUrea		0.643	4.4792***	0.503	5.766***
lnDAP		0.799	1.7318**	0.966	2.269**
lnOxen power		0.149	1.3292	0.203	2.190**
lnHerbicide		0.017	0.1909	-0.038	-0.558
Inefficiency effect model					
Variables	**Parameter**	**Coefficients**	**Standard error (SE)**		**t-ratio**
Constant	σ	0.696	0.352		1.98**
Education	σ	-0.345	0.150		-2.29**
Age	σ	-0.006	0.004		-1.33
Family Size	σ	0.006	0.031		0.21
Total Land	σ	-0.062	0.138		-0.449
Slope	σ	0.267	0.141		1.89**
TLU	σ	-0.002	0.022		-0.08
Off farm Activity	σ	0.359	0.159		2.25**
Improved Seed	σ	-0.539	0.193		-2.79***
Credit	σ	-0.256	0.142		-1.80**
Fragmentation	σ	0.278	0.172		1.62*
Ownership	σ	0.015	0.133		0.12
Sigma-squared		0.108	0.034		3.14***
Gamma		0.84	0.118		7.15***
LL		1.27			
Mean Efficiency		0.73			
Returns to scale		0.94			
Total sample size	N	120			

*,**and *** represents significance at 10%,5% and1% probability levels, respectively

Source: Computed from Field Survey Data, 2015/16

4.2.1.4. Input elasticity and returns to scale

Determination of elasticity is necessary for the estimation of responsiveness of output to inputs. Most of the inputs on the stochastic frontier are statistically significant and have the expected signs. As indicated in Table 12, the results of the Cobb-Douglas Stochastic Production Frontier showed that the estimated coefficients for land, labor, urea, DAP and oxen power generally conform expected positive signs except seed and herbicide had a negative sign. The results of the Cobb-Douglas Stochastic Production Frontier showed that maize plot, the amount of seed, urea, DAP and pre-harvest oxen power inputs were found to

be important variables in increasing the productivity of maize. Moreover, urea was significant at 1% while the remaining four variables land, seed, DAP and oxen power were significant at 5% level. Besides, the amount of seed and herbicide were unexpected result contrary to what one would expect although herbicide was not statistically different from zero.

One of the appealing features of the Cobb-Douglas functional form is the direct interpretation of its parametric coefficients as a partial elasticity of production with respect to the input used. This attribute allows one to evaluate the potential effects of changes in the amount of each input on the output.

As shown in Table 12, the parametric coefficients or partial elasticity of significant input variables were 0.23 for area, 0.5 for urea, 0.96 for DAP, and 0.2 for oxen power. These values indicated the relative importance of each factor in maize production. Otherwise, a 1% increase in the use of land, urea, DAP and oxen power will result 0.23%, 0.5%, 0.96%, and 0.2% increase in the efficiency level of maize output, respectively. Consequently, DAP appeared as the single most important factor of production followed by Urea, land allocated to maize and oxen power in the order, respectively. This implies that, ceteris paribus, a 1% increase in DAP will increase the output of maize grain by 0.96%.

Summation of the partial elasticity of production with respect to every input for a homogeneous function (all resources varied in the same proportion) is 0.94. This represents the returns to scale coefficient of total output elasticity. If all factors are varied by the same proportion, the function coefficient indicates the percentage by which output will be increased. In this case, the production function can be used to estimate the magnitude of returns to scale. If the sum of all partial elasticity is equal to one, more than one and less than one, then the function has constant, increasing and decreasing returns to scale exists respectively. Therefore, the results showed that the variables specified in the model had inelastic effect on the output of maize production. The coefficient parameters summation of the partial elasticity 0.94 showed that maize production in the study area was operated at decreasing returns to scale. As such a 1% increase in all the specified production inputs will lead to about 0.94% increase in output. Therefore, an increase in all production inputs by 1% will increase maize yield by less than 1%. In addition, the study indicated that maize yield had the highest responsiveness to DAP, followed by urea and area allocated to maize.

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As mentioned above, the seed elasticity of maize output has the unexpected sign but statistically significant and 1% increase in seed will decrease maize output by 0.96%, ceteris paribus. This is due to the fact that yield depends on the number of plants per ha and population of plants is directly related to the appropriate quantity of seed used. Moreover, negative and significant elasticity for seed in maize production indicates that there is a reduction of output when it applied more than the recommended quantity of seed. Because a very high seed density may result in low maize output due to high competition for nutrients and a very low seed density results in low maize yield due to under utilization. These results were in full agreement with those of (Wassie, 2012; Abba, 2012; Isaac, 2011).

4.2.1.5. Variability of output from the frontier due to technical efficiency differentials

It is shown in Table 12 above that both ^{2} and were statistically significant, respectively and showing the existence of significant variation from the frontier function and the importance of the technical inefficiency effects in studying the maize production system in the District. The total variation of output from the potential may not necessarily be caused totally by the efficiency differentials among the sample households. In view of this, it is necessary to determine the variability of the output in maize production in the study area attributed to each error components.

The Maximum Likelihood estimation of the frontier model was used to compute the value for the parameter ( ), which is the ratio of the variance of the inefficiency component to the total error term ($= {}_u{}^2 / ({}_v{}^2 + {}_u{}^2) = {}_u{}^2 / {}_s{}^2$. The value indicated the relative variability of the one sided error term to the total error-term. One to the farmer's inefficiency problem, which is under his/her control, and the other one is to the random variation/or usual noise component, which is beyond the control of the farmer. In other words, the extent of variability between observed and frontier output that is affected by the technical inefficiency was measured.

As a result, the total variation in output from the maximum may not have necessarily caused efficiency differentials among the sample smallholder farmers. Hence, the disturbance term had also contributed in varying the output level. In this case, it was crucial in determining the relative contribution of both usual random noises and the inefficiency component in total variability. The closer the ratio to one, the more the output variability is affected by technical inefficiency than the usual random variability. The TE analysis revealed that technical efficiency score of sample smallholder farmers varied from 28% to 95%, with the mean

efficiency level being 73%. This variation was also confirmed by the value of gamma ( ) that was 0.84. The gamma value of 0.84 suggested that 84% variation in output was because of the differences in technical efficiencies of smallholder farmers in Fogera while the remaining 16% was as a result of the effect of the disturbance term. Moreover, the corresponding variance ratio parameter implied that 27 % differences between observed and maximum frontier output for maize was by reason of the existing differences in efficiency among the sample smallholder farmers. These provided opportunity for improving maize output by investigating factors that influence efficiency in order to improve the productivity of maize in the study area.

4.2.1.6. Value of farm level technical efficiency score

Table 13. Summary of technical efficiency differentials among sample smallholder farmers

Efficiency category	Mean value	No. of sample smallholder farmer	%	Std. Deviation	Minimum	Maximum
0.25-0.51	0.41	16	13.3	0.01	0.28	0.5
0.52-0.6	0.55	10	8.4	0.03	0.52	0.59
0.61-0.73	0.68	25	20.6	0.01	0.61	0.73
0.74-0.85	0.81	37	30.8	0.06	0.74	0.85
Above 0.85	0.89	32	26.6	0.07	0.86	0.95
Total	**0.73**	**120**	**100**	**0.16**	**0.28**	**0.95**

Source: Computed from Field Survey Data, 2015/16

The indices of TE indicated that if the average smallholder farmer of the sample could achieve the TE level of its most efficient counterpart, then average smallholder farmers could increase their output by 23% approximately [that is, 1- (73/95)] (Table 13). Similarly the most technically inefficient smallholder farmer could increase the production by 70.5% approximately [that is, 1- (28/95)] if he could increase the level of TE to his most efficient counterpart. Since the mean TE is 73%, it can be deduced that 27% of the output was lost due to the inefficiency in maize producing system or in the inefficiency among the sampled smallholder farmers or both combined. Likewise on average, output can be increased by at least 27% while utilizing existing resources and technology given the inefficiency factors were fully addressed. It also indicated that smallholder farmers in the study area, on average, can gain higher output growth at least by 23% through the improvements in the technical efficiency.

Moreover, from the total sample smallholder farmers, two third of sample smallholder farmers scored above the mean TE score while almost one third of sample respondent produces less than the mean TE score of smallholder farmers in their vicinity. As a result, the wide variation in technical efficiency estimates is an indication that smallholder farmers were still using their resources inefficiently in the production process and there is still exists opportunities for improving on their current level of technical efficiency. This result suggests that a few smallholder farmers were not utilizing their production resources efficiently, indicating that they were not obtaining maximum output from their given quantity of inputs.
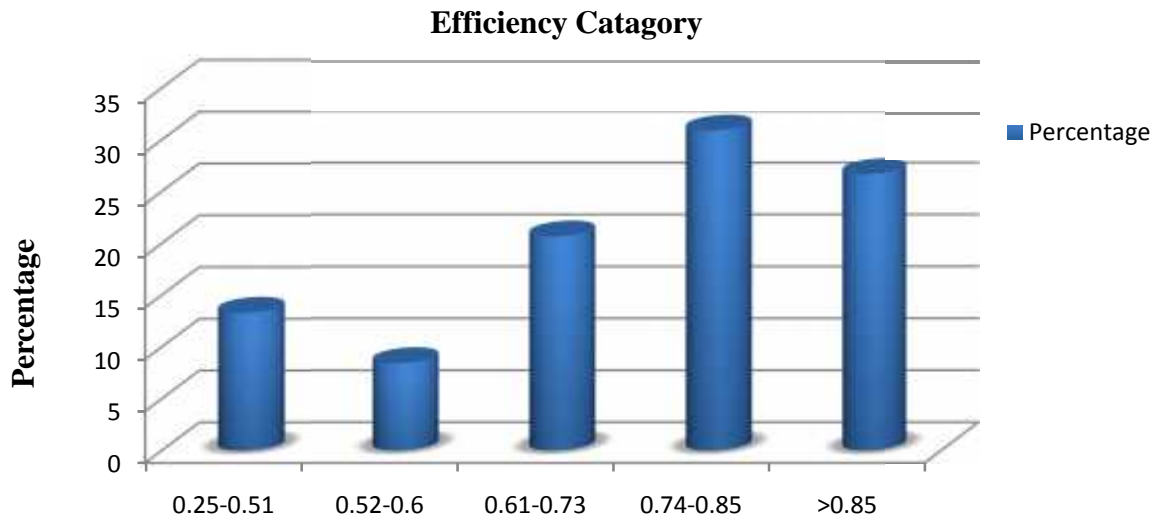
Figure 9: Frequency distribution of technical efficiency

Source: Computed from Field Survey Data, 2015/16

4.2.1.7. Input use and technical efficiency

Grouping the levels of individual technical efficiency scores into certain classes can give better picture about the distribution of individual efficiency scores. Grouping of sample respondent based on their efficiency score was based on the relative performance of each sample smallholder farmers to the mean efficiency level. According to Nyagaka, (2010) grouping can also be done based on the relative performance of each sample smallholder farmer to the mean performance level. In this case, sample smallholder farmers were categorized into three groups based on the mean efficiency and the corresponding standard deviation. The sample smallholder farmers were considered as less efficient if they were operating at less than the mean minus standard deviation, more efficient if they were operating at more than the mean plus standard deviation and of average. Accordingly there were only two groups and none of the smallholder farmers were categorized under more efficient category given the mean and standard deviation of the efficiency scores. The

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efficiency percentage in input utilization and corresponding yield obtained from the sample smallholder farmers in each groups (Table 14).

Table 14. Utilization of production inputs and technical efficiency differentials per hectare

Efficiency Group	Group category	Group (%)	SD	TE score	Yield (Qt)	Oxen (OD)	Labor (MD)	Seed (Kg)	Urea (Kg	DAP (Kg)	Herb (Lt)
Moderately efficient	0.56-0.95	83	0.16	0.79	14	11.13	13.50	25	36	52	0.76
Less efficient	Below 0.56	17	0.15	0.43	6	9.9	12	20	41	58	0.64
Overall mean	**0.28-0.95**	**100**	**0.16**	**0.73**	**12.6**	**10.52**	**12.76**	**23.79**	**38.58**	**53.97**	**0.71**

Source: Computed from Field Survey Data, 2015/16

Input use and yield varied across the two assumed efficiency group were summarized based on the technical efficiency score. Overall efficiency score was approximately 73% with standard deviation of 16%. Producer`s having average efficiency score utilized more human labor and improved seed than producers who were technically less efficient.

The input utilization across various levels of technical efficiency score was also analyzed. The group possessing average TE efficiency used 11.13 oxen days and 13.5 MD per hectare in pre harvest agricultural operations. In addition, they used improved seed 25 kg per ha and less efficient group used 20 kg per ha. It implied that less efficient group of smallholder farmers used very less quantity of improved seed as compared to the most efficient smallholder farmers (Table 14).

On the other hand, the application of inorganic fertilizers for average and less efficient smallholder farmers were different. In addition, the less efficient group used low level of management as reflected through less human labor days used in production. Thus, the clear reason for low inefficiency appears to use less labor in crop production and less area allocated under local varieties of seed. Though 83% of the sample smallholder farmers were categorized under more efficient but was found to use less than recommended level of fertilizer. For example, the amount of Urea fertilizer used by the most efficient smallholder farmer was slightly less than half of the recommended dozens of 100Kg/ha while the quantity of the DAP used was higher than the half of recommended rate. Even though, the issue of technical efficiency is not related only to maximum yield but also less input use for a given output, the less efficient smallholder farmer's yield was 6 Qt per ha.

4.2.1.8. Estimated actual and potential level of maize output

The knowledge of the individual smallholder farmer efficiency level and their corresponding actual output enables to determine how much yield is lost because of efficiency problems in the current production practice. The difference between the actual level and the frontier level of output was computed by estimating the individual and the mean level of frontier output. Similarly, it is possible to find out the potential level of production that could have been produced by the smallholder farmer had there been efficient use of the existing resources. From the relationship of technical efficiency in a given period of time as the ratio of the actual output to the potential output applying (Equation 24) below the potential attainable level of maize yield per ha of each individual farmer was obtained as follows:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{f(X_i;\beta)\exp(v_i - \mu_i)}{f(X_i;\beta)\exp(v_i)} = \exp(-\mu_i)$$

Then, solving for Y_i^*, the potential yield of each sample smallholder farmer is represented as:

$$Y_i^* = \frac{Y_i}{TE_i} = f(X_i; \beta)\exp(v_i) \tag{24}$$

Where TE_i = Technical efficiency of the ith sample smallholder farmer in maize production

Y_i^* = The potential output of the ith sample smallholder farmer in maize production, and

Y_i = The actual/observed output of the ith sample smallholder farmer in maize production

Using the values of the actual output obtained and the predicted technical efficiency indices, the potential output was estimated for each sample smallholder farmers. The mean levels of the actual and potential output during the production year were 12.59 Qt/ha and 16.24 Qt/ha, with the standard deviation of 5.72 and 5.31, respectively (Table 15). Moreover, paired sample t-test was used on the actual and potential yield to compare the difference in the amount of yield between two scenarios. There was a significant difference between potential yield and actual yield. The mean difference of the actual and the potential output was found to be statistically significant at 1% probability level. As a result, it indicates that there is a room to increase the production level on average by 3.65 qt per ha with the existing level of input use. Figure 10 illustrated that under the existing practices there was a scope to increase maize yield following the best practiced smallholder farmers in the area.

Table 15. Comparison of estimated actual yield and potential maize yield

Efficiency category	Potential yield per hectare		Actual yield per hectare	
	Mean	Std. Deviation	Mean	Std. Deviation
0.25-0.51	12.25	4.95	6.01	5.42
0.52-0.6	16.41	3.85	10.41	7.34
0.61-0.73	14.33	4.47	9.57	8.23
0.74-0.85	16.11	3.54	13.51	5.74
Above 85	19.51	6.24	17.84	9.85
Averagely efficient	17.81	8.34	15.67	6.87
Less efficient	13.51	6.65	8.25	4.49
Overall	16.24	5.31	12.59	5.72

Source: Computed from Field Survey Data, 2015/16

Potential yield was also calculated for each smallholder farmer and the results were presented by range of technical efficiency group. In general, for the less efficient smallholder farmers the recorded average actual yield was 6 qt/ha. Their corresponding average efficient group potential yield was 14qt/ha. On the other hand, the net magnitude of yield improvement through efficient utilization of existing resource for less and average efficient smallholder farmers were approximately 5.26 and 2.14qt/ha. At District level, working towards improving the efficiency of the smallholder farmers could bring additional yield of 438 qt of maize given 57.13 ha of total land area allocated for maize production in the study period. These findings may invite attention of the policy makers and District experts to improve the efficiency of the smallholder farmers through adoption of right strategy to efficiently utilize the existing resource to improve the food security of the District. Figure 10 depicted that the actual and potential production levels of sample smallholder farmers in the production of maize in the study area.
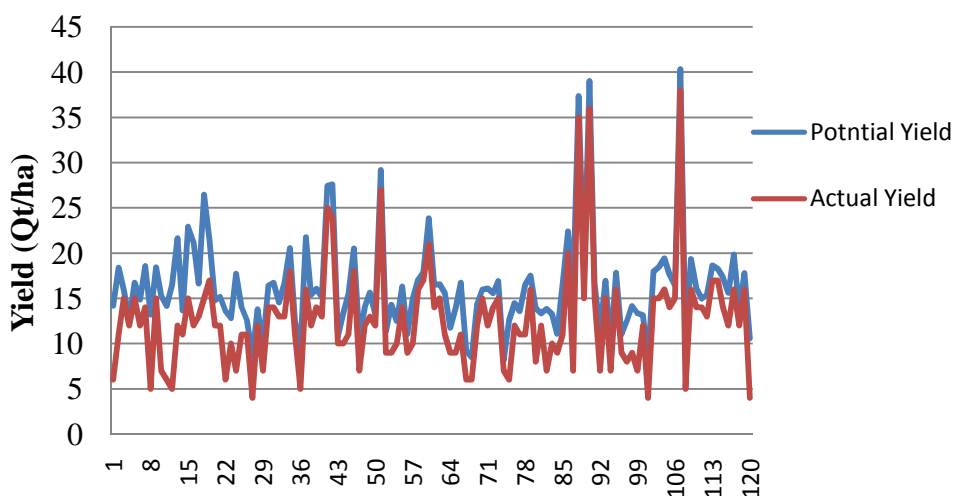
Figure 10: Comparison of the actual and potential level of maize yield per ha
Source: Computed from Field Survey Data, 2015/16

4.2.2. Determinants of Technical efficiency

The focus of this analysis was to provide an empirical evidence of the determinants of productivity variability/inefficiency gaps among smallholder farmers in order to improve the existing level of efficiency in the study area. Most literatures used to analyze determinants of efficiency rather than inefficiency. However, the only difference between them is only on the interpretation (Solomon, 2014). Merely having knowledge that smallholder farmers were technically inefficient might not be useful unless the sources of the inefficiency were identified. Thus, in the second stage of this analysis, the study investigated farm and smallholder farmer specific attributes that had impact on smallholder farmers' technical efficiency.

The parameters of the explanatory variables in the inefficiency model were simultaneously estimated in a single stage estimation procedure using computer program, FRONTIER 4.1. The inefficiency variables in the study were classified under three categories. These were the socio economic and demographic factors (education, age and family size), resource related factors (total farm size, slope of land, livestock holdings, off-farm income activities, improved seed variety, maize plot fragmentation and ownership of land), and the credit access as an institutional factor. The dependent variable of the model was inefficiency and the negative signs implied that an increase in the explanatory variable would decrease the corresponding level of inefficiency (i.e. improvement of efficiency), and the positive sign is interpreted inversely.

It is important to note that these coefficients should not be directly interpreted rather it only indicated the direction of the effects that the variables had on inefficiency and hence marginal effects using the formula recommended by Coelli and Battese, (2006) would be calculated later.

Table 12 above showed that the coefficients of explanatory variables in the technical inefficiency model results estimates. Among the 11 explanatory variables entered in the analysis 4 variables namely age, family size, off-farm income and land ownership have appeared with unexpected signs, of which off-farm income was statistically significant and the remaining explanatory variables were insignificant. Furthermore, the results of the 5 inefficiency variables conform to the priori expectations, in their signs and significance level as well in determining inefficiency /efficiency of maize production in the study area. While

the remaining 2 variables of total land and TLU showed the expected sign but did not turn out significant.

Before discussing the significant determinants of inefficiency in maize production it is important to see how efficiency and inefficiency were interrelated. The result can be presented in terms of efficiency or in terms of inefficiency. The above result is presented in terms of inefficiency and hence the negative sign shows the increase in the value of the variable attached to the coefficient means the variable negatively contributes to inefficiency level or conversely it contributes positively to efficiency levels. Thus any negative coefficient happens to reduce inefficiency which implies its positive effect in increasing or improving the efficiency of the firm vice versa.

Accordingly, the negative and significant coefficients of education, improved seed and credit indicated that improving these factors contribute to reducing technical inefficiency (Table 12). Whereas, the positive and significant variables of slope, off-farm income and fragmentation, affected the technical inefficiency positively that increase in the magnitude of these factors aggravated the technical inefficiency levels.

The implications of significant variables on the technical efficiency of the smallholder farmers in the study area were discussed below this.

Education: Education is important to increase the managerial capacity of the smallholder farmer's in decision making. The results showed that smallholder farmers with more years of formal and informal schooling were more efficient than their counterparts (Table 12). As expected, education affects the technical inefficiency effect of maize production significantly and negatively at 5% level of significance. The negative sign implies that smallholder farmers that were more educated tends to be more efficient in agricultural production than the less educated ones. Education enhances the acquisition and utilization of information on improved technology by the smallholder farmers. Similar results had been reported in studies which had focused on the association between formal education and technical efficiency (Getachew and Bamlak, 2014; Wondimu, 2013; Agerie, 2013; Shumet, 2011; Beckhman *et al.,* 2010). In general, more educated smallholder farmers were better able to generating off-farm income, utilize credit access, slope and fertility management, adopt improved technologies and purchased the appropriate quantities of inputs such as improve seed, DAP, Urea, and planting materials much faster than their counterparts. This result was consistent with the findings of

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Abdulai and Huffman, (2000) which established that an increase in human capital will augment the productivity of smallholder farmers.

Slope of maize plot: Slope has strong influence on the long-term characteristics and viability of the farming system. This implies that the steeper plot is more vulnerable to erosion than the plain plot. Hence, on the steep slope plots under continuous cultivation and with little fertility maintenance, soil fertility deteriorates overtime. This leads to the decline of the productivity of farm land. Thus, the slope of maize plot was hypothesized to have a negative effect on the technical efficiency of the smallholder farmers. It was found to be an important explanatory variable of technical efficiency of maize producer sample smallholder farmers (Table 12). The results showed that the steep slope of maize plot was contributed positively and significantly to increase technical inefficiency at 5% level of significance. This implies that the steeper maize plot is more vulnerable to erosion than the plain plot or determines efficiency negatively. This is the result of no well organized soil conservation activities which protect flooding. In this case, steep maize plots were vulnerable to erosion damage and they were likely infertile compared to plain maize plots. This result is in full agreement with (Ruth, 2011; Alemayehu, 2010 and Wondimagegn, 2010).

Off farm income: Off-farm income had a positive and statistically significant effect on technical inefficiency at 5% level of significance. This implied that for the Fogera maize producing smallholder farmers the inefficiency the coefficient of off-farm income variable was positive, indicating that the smallholder farmers who were engaged in generating off-farm income tended to exhibit lower technical efficiency levels in maize production. The negative relationship is attributed to the fact that off-farm income activity reduce that is invested their full concentrations in farming activity of higher productivity or involvement in off-farm activity are accompanied by reallocation of time away from farm related activities to generating income, such as adoption of new technologies, slope and fertility management, and gathering of technical information that is essential for enhancing production efficiency. This finding was in agreement with that of (Teklemariam, 2014; Bealu *et al.,* 2013; Hassen *et al.,* 2012; Shumet, 2011).

Improved seed: The coefficient of the dummy variable representing use of improved seeds was statistically significant and negatively appeared at 5% level of significance as expected. The negative sign of the estimated coefficients of improved seeds had important implications of positively contributes on the technical efficiency of the maize producer smallholder

farmers in the study area. It means that the tendency for any maize producer smallholder farmers to increase the production depend on the type and quality of improved seed available at the right time of sowing. This is because of improved maize seed would be so many advantageous like high yielding, disease resistant and produce at a minimum cost. Despite the gains in technical efficiency, about 37.5% of the smallholder farmers used improved seeds. This is probably because of high prices for improved seeds, making them unaffordable credit and education access to the study area of maize producer smallholder farmers. The other maize producer smallholder farmers use recycled seeds. This was in agreement with the findings of (Solomon 2014; Rudra *et al.* 2014; Endrias *et al.,* 2013; *Geta et al.,* 2013; Hassen *et al.,* 2012).

Access to Credit: The coefficient of credit recipient has consistent with the previous expected negative sign and statistically significant effect on technical inefficiency at 5% level of significance. The negative sign shows that credit recipient are more efficient than their counterpart of non-recipient. This implies that access to credit is a significant factor in enhancing efficiency of maize producer smallholder farmers in the study area. These findings can be attributed to the fact that credit permits a sample smallholder farmer to enhance efficiency by overcoming liquidity constraints. Hence, use of credit access ensures timely acquisition and use of agricultural inputs such as improved seed, DAP, Urea, herbicide, education and implement farm management decisions on time and these results increased production of efficiency. This suggests that availability of credit is an important factor for attaining a higher level of technical efficiency. Technically inefficient sample smallholder farmers can possibly get more efficient in the short run by facilitating access to credit. This empirical result is supported by the findings of (Musa *et al.,* 2014; Kwabena *et al*., 2014; Bekele , 2013; Shumet, 2011; Biforin *et al.,* 2010) found positively and statistically significant relationship between credit and efficiency. If production credit is invested on the farm, it is expected that this will lead to higher levels of output. Thus, access to credit is more likely to lead to an improvement in the level of technical efficiency.

Land Fragmentation: The variable represents the number of parcels of maize land (number of maize plots), on which the smallholder farmer grows maize. It was hypothesized that a smallholder farmer with more number of maize plots is more inefficient than a farmer with more consolidated area. The reason is that as the number of maize plots operated by the smallholder farmer increases, the smallholder farmer was unable to distribute labor resources for different activities. Moreover, the smallholder farmers that have large number of maize

plots would be wasted their time in moving between plots. The number of maize plot (fragmentation) used on the inefficiency model was appeared positive sign and statistically significant at 10% level of significance with consistent the previous hypothesized expectation (Table 12). This implied that, smallholder farmers that have large number of fragmented maize plots have the higher probability of wasting time of by moving different maize plots or unable to distribute labor resources, which results to decrease the efficiency of maize production. Furthermore, this result is congruent to with (Kifle, 2014; Getachew and Bamlak, 2014; Bekele, 2013; Beckhman *et al.,* 2010).

4.2.3. Marginal Effects of inefficiency variables

The marginal effects of explanatory variables from FROTIER analysis were computed following the procedure proposed by McDonald and Moffitt, (1980) and Maddala, (1999). This is called McDonald-Moffitt's decomposition. The derived values for the significant explanatory variables indicated that the effects of a unit change in those variables. The estimated parameters on the inefficiency model presented in Table 16 only indicated the direction of the effects that the variables had on inefficiency levels (where a negative parameter estimate shows that the variable reduces technical inefficiency). In contrast, the marginal effect presented on Table 16 below indicates the effect of inefficiency variables on technical efficiency level. According to Coelli and Battese, (2006), quantification of the marginal effects of inefficiency variables on technical efficiency was done by partial differentiation of the technical efficiency predictor with respect to each variable in the inefficiency function. The marginal effects represented by the equations above (21) were calculated by the STATA command mfx, which was complemented by specific options that allowed the estimation of marginal effects of change in explanatory variables.

Table 16. Marginal effect of efficiency variables among sample household heads

variables	dy/dx	Std. Err.	z	Change in TE in %
Education	0.108**	0.062	3.73	10.8
Slope	- 0.041*	0.064	-2.64	4.1
Off farm income	- 0.071*	0.061	2.16	7.1
Seed Variety	0.072*	0.060	2.21	7.2
Credit	0.276**	0.076	3.59	27.6
Fragmentation	- 0.353***	0.068	5.14	35.3

*,**,*** implies significant at 10% and 5% and 1% probability level, respectively

Source: Computed from Field Survey Data, 2016/17

Table 16 shows the marginal effect of the efficiency measuring variables (this table is interpreted differently, a positive sign indicate an increase in TE). Producers who use improved maize seed are 7.2% more efficient than those that do not, ceteris paribus. Therefore, in order to increase the yield, they probably need to improve the quality of maize seeds rather than the quantity of seed. The marginal change (gain in TE) for an additional year of school is 10.8%. This indicated that for considered smallholder farmers an increase in the year of school, on average will increase the technical efficiency by 10.8 %. In contrast the marginal effect (-0.041) of slope for technical efficiency indicated that, an increase in slope, on average his technical efficiency will decrease by 4.1%. The marginal effect for credit can be interpreted as, if a smallholder farmer gained credit access, the smallholder farmers technical efficiency will increase on average by 27.6 % higher than those smallholder farmers who did not receive any credit access. Finally, participation in off-farm income earning activity and fragmentation of land reduces technical efficiency by 7.1% and 35.3 % than those they did not participate in off-farm activity and having fewer fragments, respectively. This result is in full agreement with Wondimu, (2013) and Endrias *et al.,* (2013).

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary and Conclusions

The main aim of this study was to analyze determinants of technical efficiency of smallholder farmer maize production system in Fogera district. This was achieved by measuring the efficiency of smallholder farmers and identifying the determinant factors of technical efficiency that influence technical efficiency of maize production. The study used a stochastic frontier model and employed the cross sectional data of 2015/16 production year covering randomly sampled 120 smallholder farmers in three kebeles. The sample smallholder farmers were drawn in three stage sampling technique.

The study area has crop-livestock mixed farming system. The major cereal crops grown based on the area and quantity proportion are maize, teff, rice and finger millet (on ascending order). Regarding livestock production, dominated by cattle is also as equally important component of the farming system as that of crop production. Production of maize by smallholder farmers in Fogera district plays a vital role in alleviating poverty, since maize is the staple food in the District.

To achieve the objective of the study, both descriptive (using EXCEL, SPSS and STATA) statistics and econometric estimation (using FRONTIER Version 4.1 computer software) were applied. The choice of appropriate stochastic functional form of the Cobb-Douglas functional form (since trans-log was rejected), with half-normal distribution of μ (truncated normal distribution of μ was rejected), was found to be best fit the data and was applied to estimate the level of individual technical efficiency. The existence of inefficiency and the joint explanatory power of the considered inefficiency effect variables were formally tested. Accordingly, Parameters of the stochastic frontier function (from which efficiency scores have to be measured) and inefficiency effects model were account thus, estimated by the maximum likelihood methods in a single stage estimation procedure using Frontier Version 4.1 computer program. Moreover, the production structure was characterized by decreasing returns to scale since summation of the inputs coefficient is 0.94. The implication of such a result is that a proportional increase in all the factors of production leads to a less than proportional increase in output.

The results obtained from the stochastic frontier estimation showed that inefficiency was present in maize production among smallholder famers. Sufficient evidence of positive

relationship between maize productivity and higher use of intermediate inputs such as DAP, Urea and maize plot utilization were practiced. The results of efficiency analysis showed that smallholder farmers could improve their efficiency by operating closer to production frontier. Thus, there existed considerable scope to expand output and also productivity by decreasing the average yield gap between the most efficient and less efficient farm smallholder farmers. At District level, working towards improving the efficiency of the smallholder farmers could bring additional gross output of 438 quintal of maize given 57.13 ha of total land area allocated for maize production.

This amount of output and efficiency in the utilization of production input could be obtained significantly by paying more attention to the determinants of technical efficiency. Some of the areas which demand more attention were availability of DAP, Urea and adoption of recommended seed practices in maize cultivation. In addition technical efficiency increased with the increased in education, credit and improved maize seed whereas slope, off-farm participation and fragmentation decreased efficiency. Thus, it was needed in a priority basis to invest in public education to explore credit access and supply improved seed for the farm operation.

The mean technical efficiency level of sample households was about 73% with the minimum and maximum of 28% and 95%, respectively. This implies that there is a possibility to enhance maize output from the existing level if appropriate reallocation of basic inputs measures is given due attention. The value of the discrepancy ratio, , calculated from the Maximum Likelihood estimation of the frontier was 0.84 with the standard error of 0.11. The coefficient of 84% of the variability in output for maize producer sample smallholder farmer was attributed to technical inefficiency effect, while the remaining about 16% variation in output is due to the effect of random noise.

In general, an important conclusion stemming from this study is that, there exists a considerable room to reduce the level of technical inefficiency of maize production in the Fogera district. Thus, integrated development efforts that will improve the existing level of input use and policy measures towards decreasing the existing level of inefficiency will have paramount importance in improving the food security of the study area.

5.2. Recommendations

Based on the above results, the following important recommendations were given:

The study confirmed that there is an indication of a great potential for maize productivity improvement in utilizing the existing experiences of few better off smallholder farmers and demonstration of improved maize technologies.

The positive and statistical significance of major traditional inputs such as maize plot, DAP, Urea and oxen-days show the importance of conventional inputs in smallholder farmers implying better access and use of these inputs could lead to higher maize production and productivity in the study area. Enhancing the productivity of these factors of production is necessary.

Policy interventions should focus more on timely supply of DAP, Urea and good quality of improved seed to improve farmers' efficiency in production of maize.

Improving educational level of smallholder farmers: Education also found to be a very and should be taken into account in the measure of technical efficiency. It equips smallholder farmers with the necessary agricultural farming knowledge thereby facilitating information dissemination regarding modern agricultural technology, input utilization, technical know-how and environmental preservation that shifts their production frontier outward. Therefore, formal and informal education in agriculture must be provided for students and farmers to improve their technical efficiencies in maize production. Hence, the government should have designed capacity building programs should be arranged and executed in order to capacitate the smallholder farmers development project through vigorous grass-root level extension work, farmers' active participation, on-farm demonstration and trials and proper guidance of the farmers should be increased in the study area.

Slope of maize plot: Based on the findings of this study, it should be recommended that soil and water conservation (land management practice) measures practice should be done in order to maintain at least the existing fertility status of the steep maize plot in the short run. Otherwise, trying to increase the use of fertilizer and other inputs in steep slope plots would be wastage as it is not possible to exploit the maximum potential of inputs.

Expanding credit facilities: The study has shown that access to credit improves technical efficiency. Credit is necessary to empowers smallholder farmers to purchases inputs that they cannot afford from their own resources, which enhance production and productivity of maize. Hence, to improve technical efficiency of smallholder farmers for the revival of agriculture through credit accessibility, there must be a reduction in the interest rate of ACSI and collaterals of banks on loans which will facilitate credit accessibility to smallholder farmers. The limited access to credit in the study area of smallholder farmers could be due to high interest rate and also high bureaucracies involved to securing loans. Reduction in the interest rate and bureaucracies will then improve technical efficiency of maize production.

In general, the existence of higher technical inefficiency in the study area indicates that integrated development efforts that will improve the existing level of input use and policy measures that will decrease the existing level of inefficiency of smallholder farmers will have great importance in improving the living standard of smallholder farmers at large. Given limited resources, it would be wise and obviously better for the government and other concerned parties (like NGOs) participating in developmental activities to encourage development endeavors towards improving the level of efficiency of smallholder farmers in the study area as compared to introduction of new technologies. However, the continuation of technology development and its dissemination is indispensable and both ways of increasing productivity have to be followed, although priority should be given to the improvement of efficiency of inefficient smallholder farmers.

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7. APPENDICES

7.1. Appendix I. List of Tables in the Appendices

Appendix Table 1: Conversion factors used to compute man day equivalent

Age group (Years)	Man Days Equivalent (MDE)	
	Male	Female
<10	0	0
10-13	0.2	0.2
14-16	0.5	0.4
17-50	1.0	0.8
>50	0.7	0.5

Source: Storck *et. al.,* (1991)

Appendix Table 2: Conversion factors used to estimate Tropical Livestock Unit

Animal Category	TLU
Cow and Ox	1.00
Heifer	0.75
Young bull	0.80
Calf	0.25
Weaned Calf	0.34
Sheep and Goat (adult)	0.13
Sheep and Goat young	0.06
Donkey (adult)	0.70
Donkey (young)	0.35
Chicken	0.013
Horse and Mule	1.10

Source: Storck *et al.,* (1991)

Appendix Table 3: Variance inflation factor for the variables entered in to the SPF model

Variable	R	R^2	$1-R^2$(Tolerance)	VIF
Seed	0.65	0.42	0.58	1.73
Urea	0.64	0.41	0.59	1.71
Oxpw	0.62	0.39	0.61	1.63
Lab	0.57	0.33	0.67	1.49
Area	0.56	0.32	0.68	1.48
Dap	0.51	0.26	0.74	1.35
Herb	0.5	0.25	0.75	1.33
Mean VIF				1.53

Source: Computed from Field Survey Data, 2015/16

Appendix Table 4: The VIF for the continuous variables used in inefficiency variables

Variable	R^2	R^2	$1-R^2$(Tolerance)	VIF
TotLand	0.65	0.42	0.58	1.72
TLU	0.66	0.44	0.57	1.71
Age	0.35	0.12	0.88	1.13
Famsiz	0.33	0.11	0.89	1.12
Mean VIF				1.42

Source: Computed from Field Survey Data, 2015/16

Appendix Table 5: Contingency coefficient of socioeconomic variables

	Educ	Ferty	Offainc	SeedVar	Credit	Fragmt	Ownship
Educ	1	0.094	0.099	0.206	0.230	0.137	0.075
Ferty		1	0.102	0.071	0.289	0.093	0.245
Offainc			1	0.039	0.196	0.011	0.047
SeedVar				1	0.167	0.046	0.093
Credit					1	0.061	0.083
Fragmt						1	0.221
Ownship							1

Source: Computed from Field Survey Data, 2015/16

Appendix Table 6: Type of maize seed utilized by sample smallholder farmers

Type of maize	Number of sample household heads	Mean	Std. Deviation	Percent
Local variety	75	11.24	4.19	62.5
Improve Variety	45	14.84	7.11	37.5
Total	120	26.08	11.3	100

Source: Computed from Field Survey Data, 2015/16

Appendix Table 7: Livestock holding of the Smallholder farmers

Livestock	Mean	Std. Deviation	Minimum	Maximum
Cow	2.92	1.12	0	6
Heifers	1.94	1.04	0	5
Oxen	2.36	0.67	1	4
Bulls	1.57	0.70	0	3
Calves	1.98	1.00	0	5
Sheep	4.85	2.57	0	12
Goats	4.24	2.87	0	14
Donkeys	1.48	0.69	0	4
Poultry	7.67	3.73	0	20
TLU	**9.16**	**3.69**	**0**	**23.70**

Source: Computed from Field Survey Data, 2015/16

Appendix Table 8: Econometric Parameters estimation results of the C-D and Translog

| Variables | Model coefficients(Standard error) | |
	Cobb-Douglas	Translog
Constant	0.435*(0.299)	-3.454***(0.99
Lnarea	0.253**(0.115)	2.803***(0.99)
Lnlabor	0.017(0.017)	-0.254(0.97)
Lnseed	-0.962**(0.426)	-24.118***(0.96)
Lnurea	0.526***(0.091)	0.509(0.98)
Lndap	0.966**(0.425)	24.718***(0.96)
Lnoxpw	0.203**(0.092)	2.722***(0.99)
Lnherb	-0.038(0.067)	0.137(0.82)
Lnarea^2		1.032(0.99)
Lnlabor^2		0.031(0.65)
Lnseed^2		-0.048(0.90)
Lnurea^2		0.009(0.27)
Lndap^2		-0.009(0.88)
Lnoxpw^2		-0.421(0.89)
Lnherb^2		0.123(0.97)
Lnarea* Lnlabor		0.110(0.96)
Lnarea*Lnseed		0.063(0.95)
Lnarea* Lnurea		41.639***(0.89)
Lnarea* Lndap		-42.45***(0.89)
Lnarea* Lnoxpw		-0.592(0.96)
Lnarea* Lnherb		-0.146(0.88)
Lnseed*Lnurea		-0.031(0.54)
Lnseed* Lnherb		0.092(0.88)
Lnurea*Lndap		0.029(0.89)
Lndap*Lnoxpw		-0.029(89)
Lnoxpw* Lnherb		-0.052(85)
Sigma-squared	0.108***(0.03)	0.141(0.72)
Gamma	0.842***(0.12)	0.972(96)
Mean efficiency	0.73	0.75
LL function	1.27	14.45

*, **, *** implies significant at 10%, 5% and 1% probability level respectively

Source: Computed from Field Survey Data, 2015/16

Appendix Table 9: Technical efficiency estimate per plot unit of analysis

Farmer ID	TE	Farmer ID	TE	Farmer ID	TE	Farmer ID	TE
1	0.40	31	0.78	61	0.85	91	0.88
2	0.55	32	0.89	62	0.88	92	0.55
3	0.93	33	0.73	63	0.70	93	0.87
4	0.94	34	0.82	64	0.71	94	0.66
5	0.85	35	0.86	65	0.61	95	0.87
6	0.71	36	0.50	66	0.62	96	0.75
7	0.67	37	0.71	67	0.59	97	0.63
8	0.36	38	0.72	68	0.64	98	0.59
9	0.80	39	0.81	69	0.80	99	0.52
10	0.42	40	0.83	70	0.93	100	0.90
11	0.41	41	0.88	71	0.72	101	0.44
12	0.28	42	0.83	72	0.89	102	0.80
13	0.50	43	0.92	73	0.89	103	0.76
14	0.74	44	0.69	74	0.80	104	0.78
15	0.57	45	0.68	75	0.43	105	0.74
16	0.53	46	0.87	76	0.78	106	0.88
17	0.73	47	0.61	77	0.81	107	0.94
18	0.52	48	0.83	78	0.65	108	0.46
19	0.76	49	0.83	79	0.90	109	0.76
20	0.81	50	0.90	80	0.56	110	0.85
21	0.78	51	0.91	81	0.89	111	0.92
22	0.43	52	0.72	82	0.46	112	0.83
23	0.74	53	0.56	83	0.65	113	0.89
24	0.37	54	0.79	84	0.77	114	0.92
25	0.72	55	0.80	85	0.61	115	0.75
26	0.87	56	0.73	86	0.87	116	0.74
27	0.42	57	0.66	87	0.40	117	0.77
28	0.86	58	0.94	88	0.93	118	0.83
29	0.71	59	0.95	89	0.85	119	0.85
30	0.80	60	0.86	90	0.92	120	0.35

Source: Computed from Field Survey Data, 2015/16

7.2. Appendix II. Interview Schedule

UNIVERSITY OF GONDAR

College of Agriculture and Rural Transformation (CART)
Department of Agricultural Economics

Dear Respondents: This interview schedule is prepared to undertake a study on the *"Determinants of technical efficiency in maize production of smallholder farmers; the case of Fogera district, south Gondar zone of ANRS, Ethiopia."* The information that you are going to provide based on specific questions was used only for the research purpose (thesis) and will not be disclosed for any third party. You were kindly requested to participate in filling the questions.

General information

ID number of the household head_____   Date of interview_____

Enumerator name _____   Signature of the enumerator_____

Socio-demographic Information of the household

1. Kebele _____
2. Name of the household head_____
3. Farming experience_____ years
4. Sex :   1.male   2.female
5. Age in completed year_____
6. Marital status   1. Single   2. Married   3. Widowed   4. Divorced
7. Educational level   Illiterate=1;   Only R & W=2;   literate= grade completed
8. Religion   1. Orthodox   2. Muslim   3. Protestant   4. Catholic   5. Others
9. Family members of the HHH in No. _____

Sex	Age Category					Remark
	<10	**10-13**	**14-16**	**17-50**	**>50**	
Male						
Female						

Land use and possession in 2015/16

10. Total Area of land_____ (ha)

10.1. Owen land_____ ha   10.4. Crop land_____ ha

10.2. Rented in_____ ha   10.5. Maize plot size_____ ha

10.3. Shared in_____ ha   11. Grazing land _____ ha

Livelihood Sources of the Household head

11. Plot characteristics and amounts of maize production in 2016

Crop type	Plot No. (Fragment)	Plot size (ha)	Plot distance (walking minutes)	Ownership *1=own 2=rented in (price/ha) 3=share cropped (amount of share to the operator)*	Soil fertility *1=good 2=low*	Slope *1=plain 2= steep*	Production(qt) Main produ. (Yield)	By-product
Maize								

11.1. How many quintals of maize did you ever obtain? Highest___ Medium__ Lowest ___

12. Livestock production

Type of livestock	Total number	Purpose for maintaining *1: sale 2: consumption 3: Draught 4: Others (wealth ,culture),*	Remark
Cow			
Heifer			
Oxen			
Bull			
Calves			
Sheep			
Goat			
Donkey			
Poultry			
Mule			
Beehives			

13. Inputs cost used in a plot of maize Production and plot characterization in 2015/16

Fertilizer (kg)		Manure/Compost *1=Used 0=Not used*	Seed(kg)		Amount of Herbicide use (Lt)
DAP	**Urea**		Local	Improved	

14. Off-farm opportunity & wealth conditions

14.1.   Do you have off farm income source?   1. Yes   2. No

14.2.   Which one of the following is the source of your off farm income?

   1. Off-farm activity   2. Pension payments   3. Transfer payment   4. Salary/wage

   5. Rent from asset   6. Other specify

14.3. What is the relative wealth position of the farmer? (categorized by peer groups)

   1. Very rich   2. Rich   3. Medium   4. Poor   5. Very poor

14.4.   Annual income from off farm activity? _____

Type of off farm income	No of average working day per month	Income earned from each	Total income	Expenditure	
				Details	Amount(birr)
Labor work				Food	
Charcoal making				Clothes	
Remittance				Education	
Other source				Health	

14.5. Were some of your family engaged in off farm activities?

  1. Yes   2. No   if yes why?   1. Shortage of land   2.Excess family labor

 3. Attractive income from off-farm activities   4. Other, specify_____

15. Credit access

Source of Credit 1.Amhara credit and saving institution 2. Local money lenders 3. Relatives 4. Cooperatives 5.Traders 6. From banks	Amount of credit	Purpose of credit 1. DAP and UREA 2. Seed purchase 3. To send students to school 4. Home consumption 5. Others	Distance of credit source Minute or Km

15.1. Of the total amount you borrowed over the last two years have paid all as per the promise?

        1. Yes   2. No

15.2. If it is not what were the Major problems in credit use? 1. inadequate amount of credit 2. high interest rate 3. untimely credit supply 4. Lack of adequate kind credit 5. Other (specify)

15.3. How much did you borrow for maize production in 2016 (Birr)?

1. fertilizer_____ 2. Seed_____ 3.Herbicide_____

16. Human labor and oxen power input used summary in maize production per plot

Activities	Pair of Oxen power		Family labor (Number)							Hired and exchange labor (Number)							Plot no & size
			Men		Women		Children			Men		Women		Children			
	No.	Hr.	17-50	>50	17-50	>50	10-13	14-16 M	14-16 F	17-50	>50	17-50	>50	10-13	14-16 M	14-16 F	
1st Plowing																	
2nd Plowing																	
3rd Plowing																	
4th Plowing																	
Sowing																	
1st Weeding																	
2nd Weeding																	
Chemi applica																	
Others																	

Key

1. Number (1, 2…)

2. Time (Hrs)

3. Age: - 01 if <10; 02 if 10-13; 03 if 14-16; 04 if 17-50; 05 if >50

4. Sex; F if female & M if male

17. What is your future plan about maize production area?

 1. increase   2. decrease   3. No change   4. depends on the conditions

18. Type of the house 1. Corrugated   2. Thatched

19. Please identify the major problems in maize production of Fogera district

i. What were the technical problems?   ii. What were the managerial problems?

   1._____   1._____

   2._____   2._____

iii. What were the infrastructural problems?   iv. Any other problems

   1._____   1._____

   2._____

   3._____

20. What is your suggestion to overcome the above problems?

_____

_____