ECONOMIC EFFICIENCY OF SMALLHOLDER FARMERS IN RICE PRODUCTION: THE CASE OF GURAFERDA WOREDA, SOUTHERN NATIONS NATIONALITIES PEOPLE'S REGION, ETHIOPIA

MSc. THESIS

BY

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ECONOMIC EFFICIENCY OF SMALLHOLDER FARMERS IN RICE PRODUCTION: THE CASE OF GURAFERDA WOREDA, SOUTHERN NATIONS NATIONALITIES PEOPLE'S REGION, ETHIOPIA

By

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A Thesis

Submitted to the School of Graduate Studies, Jimma University, in Partial fulfillment of the Requirements for the Degree of Master of Science in Agriculture (Agricultural Economics).

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Chairperson, CGS Signature Date

DEDICATION

I dedicate this thesis manuscript to my lovely wife Tadila Ashagrie and my sister Serkalem Melese.

STATEMENT OF THE AUTHOR

I declare this is my work and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc. degree at Jimma University and is deposited at university library to be made available to borrowers under rules of the library. I solemnly declare this thesis is not submitted to any other institution anywhere for the awarded of any academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

The author was born in North Shewa zone of Ethipia on September 23, 1985 E.C. He attended his elementary and junior education at Rarraty Elementary and junior school. He completed his secondary education at Arerti Secondary School. After completion of his high school education, he joined Bahir Dar University in October 2005 and graduated with B.Sc. Degree in Agricultural Economics in June 2007 E.C.

In October 2008 he joined Development Bank of Ethiopia as a junior Loan officer and worked there until February 2008 E.C. In February 2008, the author was employed in Mizan Tepi University as graduate assistant and served for six month until he joined Jimma University in October 2009 to pursue his postgraduate studies in Agricultural Economics.

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ABREVATIONS AND ACRONYMS

AE	Allocative Efficiency
ATA	Agricultural Transformation Agency
CIA	Central Intelligence Agency
CSA	Central Statistical Agency
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
EE	Economic Efficiency
EUCORD	European Union Cooperative for Rural Development
FAO	Food and Agricultural Organization
FDRE	Federal Democratic Republic of Ethiopia
FPF	Frontier Production Function
GDP	Gross Domestic Product
GLR	Generalized Likelihood Ratio
GTP	Growth Transformation Plan
GWAO	Guraferda Woreda Agricultural Office
HH	Household Head
LN	Natural Logarithm
ME	Marginal Effect
MLE	Maximum Likelihood Estimation
MoARD	Ministry of Agriculture and Rural Development
NGOs	Non-Governmental Organizations
OLS	Ordinary Least Squares
PPC	Production Possibility Curve
RSA	Regional Statistical Abstract
SFA	Stochastic Frontier Analysis
SNNPR	Southern Nations Nationalities people's Region
SPF	Stochastic Production Frontier
SSA	Sub-Saharan Africa
TE	Technical Efficiency
TLU	Tropical Livestock Unit
UNDP	United Nations Development Program

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ABSTRACT

Ethiopia is emerging as an important rice growing country in Eastern Africa. However, its performance is unsatisfactory and production stood at behind the population growth. Improving productivity through introduction of modern technologies and/or improving the efficiency of inputs will be an important alternative to fill the gap between demand and supply. Thus, the aim of this study was to measure the level of technical, allocative and economic efficiencies and to identify factors affecting these efficiencies in Gurafera woreda. Two-stage random sampling technique was used to select 148 household heads and interviewed using a structured questionnaire during 2017/18 production year. Descriptive statistics, stochastic frontier and two-limit Tobit regression models were employed. STATA version 13.0 software was used to analysis the levels of technical, allocative and economic efficiencies. As a result, the mean technical and allocative efficiencies were 78.5 and 80.56%, respectively. While the mean economic efficiency was 63.18%. The average technical and allocative efficiencies implies that there exists a possibility to increase rice production by 21.5% without using extra inputs and decrease cost of inputs by 19.44%, respectively. The Cobb-Douglas production function result indicated that, rice output was positively and significantly influenced by land, labor. Seed, oxen, herbicide and DAP. Likewise, a two-limit Tobit model revealed that economic efficiency was positively and significantly affected by education, frequency of extension contact and cooperatives membership and variables like, proximity to market and non-farm income affected it negatively. The results showed that there is an opportunity to increase the efficiency of rice production in the study area. Finally, policies target to motivate and invest in the provision of basic education, strengthen the existing agricultural extension system, organize non-member farmers in cooperative association and development of market and road infrastructures needs to improve economic efficiency of smallholder rice producers.

Key words: Efficiency, Guraferda, Smallholder Rice Producers, Stochastic Frontier, Two-Limit Tobit.

1. INTRODUCTION

1.1. Background of the Study

In the world, about 2.5 billion of rural people derive their livelihoods from agriculture. For many economies, especially those of developing countries, agriculture can be an important engine of economic growth. Approximately three-quarters of the world's agricultural value added is generated in developing countries and in many of these, the agriculture sector contributes as much as 30% to GDP (FAO, 2013). Africa with its vast land area covering 3 billion hectare (ha), 1.3 billion ha of land used for agriculture, out of which only 252 million ha (19.36 %) is arable (FAO, 2011). Specifically when we came to Ethiopia, Agricultural is the basis for economy growth. Roughly, the sector contributes 72.7% of employment, 35.8 % of GDP and 81% of foreign exports (CIA, 2018). Despite the enormous role over the past years, its importance is limited because of various factors (such as inefficiency in utilization of limited resource, lack of using modern agricultural technology, El Niño- related drought, crop disease.. etc) UNDP, 2013; WB, 2014 and FAO, 2015.

Ethiopian government has put much effort in promoting agricultural productivity and efficiency of smallholder farmers (Jema, 2008). Among this the government has designed a five years (2010/11-2014/15) GTP I and GTP II (2015/16-2019/20) which aims at boosting the national gross domestic product (GDP). According to GTP 1 smallholder farmers were the main target groups where emphasis was given to implement strategies to improve productivity by disseminating effective technologies through the scaling up and/or by improving the productive capacity of farmers. GTP II also has been formulated to carry forward the basis, objectives and strategic directions of GTP I. The achievements gained, challenges faced and lessons drawn from the implementation of GTP I was the bases for the formulation of GTP II (FDRE, 2016).

In Ethiopia agricultural productivity in general and productivity of cereals, in particular can be increased by either introduction of modern technology or by improve efficiency of inputs (labor, land, seed, fertilizer...etc) is important to boosting industrial competitiveness and accelerating structural transformation as well as reducing poverty. Moreover, full and effective implementation of the existing productive enhancing strategies, such as, consolidating the quality and coverage of agricultural extension service deliver, accelerating technological learning through strengthening social networking of farmers, strengthening effective agricultural research and implementing scientific agricultural input utilization are critical (Ibid).

Cereals are the major food crops both in terms of area coverage and volume of production obtained in Ethiopia. They produced in larger volume compared with other crops because cereals are the principal staple crops. Out of the total grain crop area, 81.27% (10,219,443.46) hectare (ha) was under cereals. Cereals contributed 87.42% about 253,847,239.63 quintals (Qt) of the grain production. They also account for 65% of the agricultural value added, equivalent to about 30% of the national GD (CSA, 2017; Shahidur *et al.*, 2010 and MoARD, 2010).

Rice (Oryza Sativa Linu) is the staple food over half of the world's population and at least 3.5 billion people are consuming rice (Hegde, 2013). In the world, the largest volume of rice production is concentrated in countries China, India, Indonesia, Vietnam, Thailand, Bangladesh, Burma, Philippines, Brazil and Japan. The percentage share of the above top ten rice producing countries accounts for about 32.9,24.4, 11.0, 7.0, 6.0, 5.4, 5.3 2.9 and 1.8 % of the world production respectively (FAO, 2013).

Rice is an important staple food crop in Africa with a growing demand that poses an economic challenge for the African continent. Annual rice production in Sub-Saharan Africa is estimated at 14.5 million metric tons (MT), comprising 15% of the region‘s cereal production. Smallholder farmers produce most of this rice. In contrast, Africa‘s rice consumption is about 21 million MT creating a deficit of about 6.5 million MT per year valued at US$ 1.7 billion that is imported annually. Overall, imported rice accounts for roughly 40% of Sub-Saharan Africa local rice consumption (Ragasa *et al*., 2013). This indicates that the region needs to increase production and productivity to fill the gap between demand and supply created in rice consumption.

Rice, become a commodity of strategic significance in Ethiopia for domestic consumption as well as export market for economic development (Hegde, 2013). Besides, it is among the target commodities that have received due emphasis in the promotion of agricultural production, as a result it is considered as the "*millennium crop"* to ensuring food security in Ethiopia (MoARD, 2010).

The production of rice started in Amhgara Region at Fogera plain and at Gambella in Ethiopia (CSA, 2013). Fogera plain contributes about 32 % of rice production in the country (Dagnine *et al*., 2015).

According to CSA (2018) in Ethiopia rice production, productivity and area allocated for rice production showed some incremental trend. This report indicates that rice production has increased from a production of 1,360,007.26 Qt, in 2017 to 1,510,183.30 Qt in 2018.While the productivity of rice has increased from 28.09 Qt/ha in 2017 to about 28.44Qt/ha in 2018 production year. Similarly, the area allocated has increased from about 48,418.09 ha in 2017 to about 53,106.79 ha in 2018. Even though, rice productivity shows some increment and brought a significant change in the livelihood of farmers, still the demand for rice over increasing than its supply, due to an over increasing population growth. Therefore, this calls for the need to establish a strong research and development system to bring about productive, sustainable, stable, and profitable rice farming system in the country (Afework, 2015).

Agriculture is the core of the economies of the overwhelming majority of inhabitants in Southern Nations, Nationalities and Peoples Region (SNNPR) of Ethiopia. It directly supports over 90% of the regions inhabitants (RSA, 2010). In Guraferda, woreda rice is one of the most important crops grown in terms of area coverage and the volume of production. For instance, the total rice yield of the woreda during the 2015/2016 production period was 56,595.21Qt, while in the 2016/2017 production period it was 61,025.22Qt. Nevertheless, the productivity did not record any increase. Instead, it fell from 19.15 Qt per ha to 18.99 Qt per ha during the above period (GWAO, 2017).The increase in the production was simply because increment of land under rice cultivation from 2,864.13 ha to 3,213.55 ha in these similar production years.

Therefore, knowledge on the level of economic efficiency of smallholder rice production and the underlying socio-economic and institutional factors causing economic inefficiency may help to assess the opportunities for increasing rice production and productivity. Thus, this study would try to measure the economic efficiency level and identify the major factors that affect efficiency level of rice production in smallholder farmers in Guraferda Woreda.

1.2. Statement of the Problem

In Ethiopia, despite socio-economic importance, the performance of the agricultural sector has been very low for several years due to many natural and manmade factors. As a result, the country has been characterized by large food self-sufficiency gap at national level and food insecurity at household level (Temesgen *et al*., 2011). However, potential areas of Ethiopia can produce enough grains they cannot meet the needs of the growing demand in the deficit areas. The inefficient agricultural systems and differences in efficiency of production discourage farmers to produce more (Naranjo, 2012).The main reason for the low level of crop production is related to shocking weather condition, amount of rainfall, poor quality of seed, old farming techniques, poor complementary services such as extension, credit, marketing, infrastructure and poor and biased agricultural policies are among the major factors that have seriously constrained the development of Ethiopia's agriculture (ATA, 2013).

Even though rice is one of the markets oriented and strategic cereal crop expected to contribute to ensuring food security in Ethiopia, still different production and marketing factors hindered and limited its productivity. Limited input supply, farmer’s inefficiency, poor adoption of technology and institutional limiting factors and other policy issues were among the variable constrained the farming system (Astewle, 2017 and Lavers, 2012). Production inefficiency among smallholder farmers in cereal production in general and rice production in particular is one of the key problems in agricultural productivity in Ethiopia.

Nevertheless the government and NGOs have made effort to increase rice productivity in Guraferda woreda, by introducing technologies (like, improved rice seed verity, fertilizer and training), the productivity did not gain the expected change. For instance, the productivity of rice in this woreda in 2016/17 production season was 18.99 Qt/ha (GWAO, 2018). This was very low as compared to the productivity of rice at Regional and National level, which were 20.02 and 28.08 Qt/ha, respectively (CSA, 2017). This implies the existence of a wide rice yield gap due to inefficiency and the possibility to increase rice output among farmers in this woreda.

Theoretically, introducing modern technology can increase agricultural output. However, in areas where there is inefficiency, trying to introduce new technologies may not have the expected impact (Tarkmani and Hardakar, 1996, cited in Jema, 2008).

Productivity can be increased through dissemination of improved technologies such as fertilizer and improved varieties and/or by improving the productive capacity of farmer. These two are not exclusive because the introduction of modern technology could not bring the expected shift of production frontier, if the existing level of efficiency is low. This implies the need for the integration of modern technologies with improved level of efficiency (Diao *et al*., 2007).

Thus, it becomes crucial to undertake economic efficiency analysis at farm level under the existing technology to enhance the contribution of the sector for national economy. In fact, inefficiency is costly both to the producing units and to the society. So, identifying the extent of inefficiency and the factors that contribute to inefficiency is a paramount importance on the level of resource use efficiency in smallholder rice producers. Such information is useful to formulating appropriate policies to reducing the level of economic incompetence (Bravo and Pinheiro, 1997).

Consequently, one way of reducing the cost of production in a farm is to increase farm output by increasing efficiency (Kumbhakar *et al*., 2008). In this regard, it is necessary to identify factors of production and quantify current levels of economic efficiency of farmers in order to estimate the losses in production attributed to inefficiency due to different socio-economic characteristics and management practices.

Many studies have provided evidences that rice production and productivity is often associated with several problems in Ethiopia. Since rice has a recent history in Ethiopia, its research status is at infant stage, almost much of the works are constrained on adoption and marketing (Abebe *et al*., 2011; Afeworke, 2015; Bosena and Agegnehu, 2016 and Asetewle, 2017). There is only one rice technical efficiency study in Amhara Region by (Tadesse *et al*., 2016). However, focusing only on technical efficiency (TE) understates the benefits that could be derived by producers from improvements in overall performance.

Moreover, there is no study done on economic efficiency (EE) of smallholder rice producers in the study area. Hence, there is a need to fill the existing knowledge gap by addressing issues related to technical, allocative and economic efficiencies of smallholder farmer's rice production in the study area by providing empirical evidence on smallholder resource use efficiency. Based on the backdrop this study also attempts to fill this research gap.

1.3. Research Questions

This study was tried to answer the following leading research questions:

1. What is the existing level of technical, allocative and economic efficiencies in rice production in the study area?
2. What are the sources of differences in technical, allocative and economic efficiencies in the study area?

1.4. Objective of the Study

1.4.1. General objective

The main objective of this study was to analyze economic efficiency in smallholder rice producing farmers in Guraferda woreda, southwestern, Ethiopia.

1.4.2. Specific objectives

1. To estimate the level of technical, allocative and economic efficiencies of smallholder rice producer in Gurafera woreda.
2. To identify the determinants of technical, allocative and economic efficiencies in the study area.

1.5. Significance of the Study

Efficiency study plays a significant role in providing useful information regarding level of inefficiency in production and helps to identify those factors, which are associated with less efficiency that may exist. The efficient allocation of resources at the farm level has great implication for overall national development. The following advantage was obtained from measuring efficiency of rice production:- It is a success indicator and performance measure, it is only by measuring efficiency and separating its effects from the effects of the production environment that one can explore hypotheses concerning the sources of efficiency differentials (Lovell, 1993). When the sources of lees efficiency were identified, policy that aims towards improving farmers' performance can be effectively done and the ability to quantify efficiency helps decision makers to monitor the performance of the rice sector under study.

Therefore, such an empirical study was certainly be useful in designing and amending different policies that were targeting to the improvement of the living standard of farmers and to ensure food security in the study area.

Hence, the result of this study was given an appropriate implication designed to increase rice productivity by identifying key sources of inefficiencies. As a result information generated from this study will help to inform the government and NGOs on the policy change and formulation of new policies in order to enhance the performance of the rice sub-sector. This was help to identify the areas of intervention, in order to maintain continuous flow of the rice products to the consumers.

1.6. Scope and Limitation of the Study

The study used SFA, which is best suited to single output, to analyze the data. The efficiency score of the frontier method are only relative to the best firm in the sample. The inclusion of extra firms may reduce efficiency scores coelli *et al.* (1998). Thus, the efficiency score in this study was relative value of the best firm in the study area. This efficiency score might be reduced if more efficient farmers from other area are included in the study. Likewise, it could increase if less efficient farmers are included.This study concentrates in Gurafera woreda with cross-sectional data for rice production. Other cereals crops in the study area were not included in the estimation of efficiency scores. Moreover, the scope of the study was limited on the EE of the smallholder rice producers of Guraferad Woreda. Finally, this study was delimited to sample size of 148 stallholder rice producers in Guraferda woreda during 2017/18 rice production season.

1.7. Organization of the Thesis

This thesis categorized in to five chapters. The first chapter dealt with background, problem statement, objective, significance, scope and limitations of the study. The second section concerned with review of literature, which includes theoretical, conceptual and analytical framework of EE and summary of empirical efficiencies study in different countries. Description of the study area, type and source of data, sampling design, data collection and method of data analysis are presented in chapter three. Chapter 4 concerned with result and discussion of descriptive and econometric model result. Lastly, conclusion and recommendations of the study are presented in to chapter five.

2. LITERATURE REVIEW

In this chapter, theoretical, conceptual and analytical frameworks of economic efficiency, methods of measuring production efficiency and recent empirical studies made on technical, allocative and economic efficiencies have been reviewed.

2.1. Theoretical Review

In this sub-section definitions and concepts of productivity, efficiency and approaches of efficiency measurement were discussed.

2.1.1. Definition and concept of productivity and efficiency

Productivity and efficiency are two different concepts except under the assumption of constant return to scale. According to Fried *et al*. (2008) productivity is the ratio of production output to what is required to produce it (inputs). In the same way, Lovell (1993) defines productivity of a production unit as the ratio of its output to its input. The measure of productivity is defined as a total output per one unit of total input. This measure is easily calculated if the farmer uses a single input to produce a single output. On the contrary, if the production unit uses several inputs to produce several outputs, then the inputs and outputs have to be aggregated so that productivity remains the ratio of two scalars.

On the other hand, efficiency is the success with which a farmer uses its resources to produce output. Farrell (1957) initiated the first analyses of efficiency measures. He introduced the notion of relative efficiency in which the efficiency of a particular decision making unit (DMU) may be compared with another DMU within a given group. He identified three types of efficiency, TE, allocative efficiency (referred to by Farrell as "price efficiency"), and economic efficiency (referred to by Farrell as "overall efficiency").TE refers to the ability of a DMU to produce the maximum feasible output from a given bundle of inputs, or the minimum feasible amounts of inputs to produce a given level of output. The former definition is referred to as output-oriented TE, while the latter definition is referred to as input-oriented TE Farrell, 1957). TE is a component of productive efficiency and is derived from the production function. Productive efficiency consists of technical efficiency and allocative or factor price efficiency.

TE is measured as the ratio between the observed output and the maximum output, under the assumption of fixed input, or, alternatively, as the ratio between the observed input and the minimum input under the assumption of fixed output (Porcelli, 2009). A TE position is achieved when the maximum possible improvement in outcome is obtained from a set of inputs. An intervention is technically inefficient if the same (or greater) outcome could be produced with less of one type of input. TE cannot, however, directly compare alternative interventions, where one intervention produces the same (or better) outcome with less or more of one resource and more of another (ibid). TE value will take a value between zero and one, and hence an indicator of the degree of technical inefficiency of the production unit. A value of one indicates the firm is fully technically efficient (Farrell, 1957).

Allocative efficiency (AE) or price efficiency refers to the ability of a technically efficient DMU to use inputs in proportions that minimize production costs given input prices. Or it's 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, observed vs optimum cost or observed profit vs optimum profit. AE is calculated as the ratio of the minimum costs required by the DMU to produce a given level of outputs and the actual costs of the DMU adjusted for TE Farrell, 1957).

EE is a combines both TE and AE. An economically efficient input-output combination would be on both the frontier function and the expansion path. Alternatively, economic efficiency refers to the proper choice of inputs and products combination according to their price relation or the ability of the firm to maximize profit by equating marginal revenue product of inputs to their respective marginal costs. If a farm has achieved both technically efficient and allocatively efficient levels of production, it is economically efficient and new investment streams may be critical for any new development (Farrell, 1957). Or EE refers to a complete minimization of economic waste either, for any observed level of output, inputs are minimized or for any observed level of inputs, outputs are maximized, or some combination of the two Coelli *et al.* (1998).

2.1.2. Approaches of measuring efficiency

Output oriented and input oriented approaches are two major approaches to measure TE. Where, the former occurs when the maximum amount of an output is produced from a given set of inputs. Input oriented on the other hand, occurs when minimum amount of inputs are required to produce a given level of output. Both measures will coincide when the technology exhibits constant returns to scale, but are likely to vary otherwise (Coelli and Battese, 2005).

2.1.2.1. Input-oriented approach

The input oriented approach addresses the question “by how much a production unit can proportionally reduce the quantities of input used to produce a given amount of output?” (Coelli *et al*., 1998). Farrell (1957) illustrated his idea about measuring efficiency of input oriented approach with figure, using two factors of production (X1 andX2) as follow. The SS’ is an isoquant represents the various combinations of the two input variables that at least a firm might use to produce a unit of output. AA' is an isocost line, which shows all combinations of inputs X1 and X2 to be used in such a way that the total cost of inputs is equal at all points. However, any firm intending to maximize profits has to produce at Q', which is a point of tangency and representing the least cost combination of X1 and X2 in production of output at point Q' the producer is economically efficient.

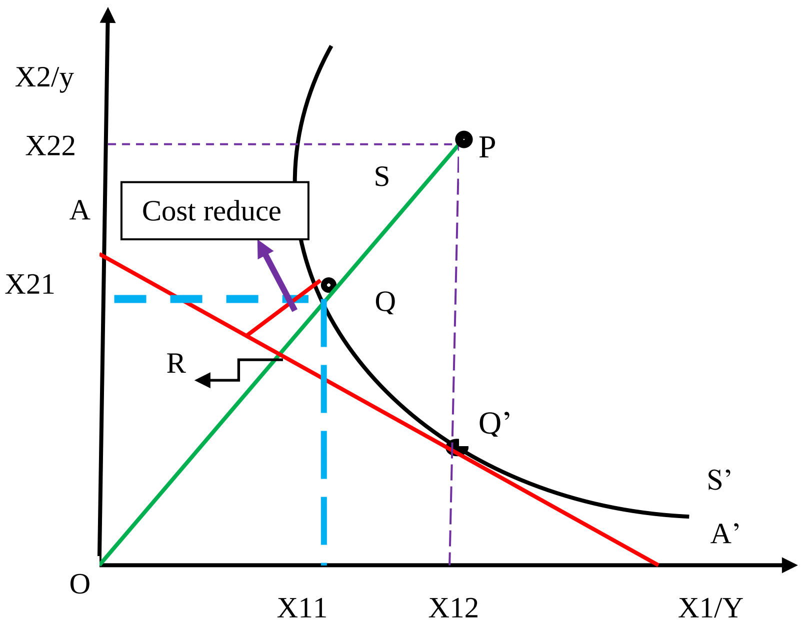

Figure 1: Input oriented illustration of technical and allocative efficiencies.

A departure from the unit isoquant indicates technical inefficiency and the more a firm are far from the unit isoquant the more it is inefficient. As illustrated in figure-1 above a firm producing at P uses inputs X12 and X22 to produce a unit output and firm Q uses X11 and X21 amount of inputs to produce the unit output given by the isoquant curve SS'. Since same amount of output is produced with different combination of input (X1andX2) on this single isoquant curve SS', firm P has over used the inputs than firm Q. Therefore this measures the level of technical inefficiency of the firm p. In other words, the farmer can produce at any point on SS' with fewer inputs (X1 and X2) technically efficient and all production inputs are optimally used. Departure from the line AA' represents the degree of allocative inefficiency (AE) and the value is given by the ratio,

$$AE = OR / OQ \qquad \text{..1}$$

The distance RQ represents the reduction in production costs that would occur if a firm is produce at both allocatively and technically efficient point Q', instead of at the technically efficient, but allocatively inefficient, point Q. Hence all farmers that produce along the isoquant are 100 percent technically efficient (Farrell, 1957). The degree of TE of such a farm is measured as,

$$TE = \frac{OQ}{OP} = 1 - \frac{QP}{OP} \qquad \text{...1.1}$$

As indicated on figure1, above the distance RQ represents the reduction in production costs that would occur if production were to occur at the allocatively and technically efficient point Q', instead of at the technically efficient but allocatively inefficient, point Q. The total economic efficiency (EE) is defined as,

$$EE = OR / OP = TE * AE = (OQ / OP) * (OR / OQ) = OR / OP \qquad \text{.................................1.2}$$

These three efficiency measures are bounded between 0 and 1. However, in practice, the isoquant is never known. Hence, the isoquants that represent the efficient points was estimated from sample data. However, the question here is how to estimate production frontiers that represent efficient points of production.

2.1.2.2. Output-oriented approach

The output-oriented approach can answer the question by how much can output be increased without increasing the amount of inputs used (Coelli *et al.*, 1998). According to Farrell (1957) output oriented measures can be illustrated by taking into account the case where production involves two outputs (Y1 and Y2) and a single input (L).If the input quantity is held fixed at a particular level, the technology can be represented by a production possibility curve that shows the possible combination of two outputs (Y1 and Y2) in two dimensions as follows:

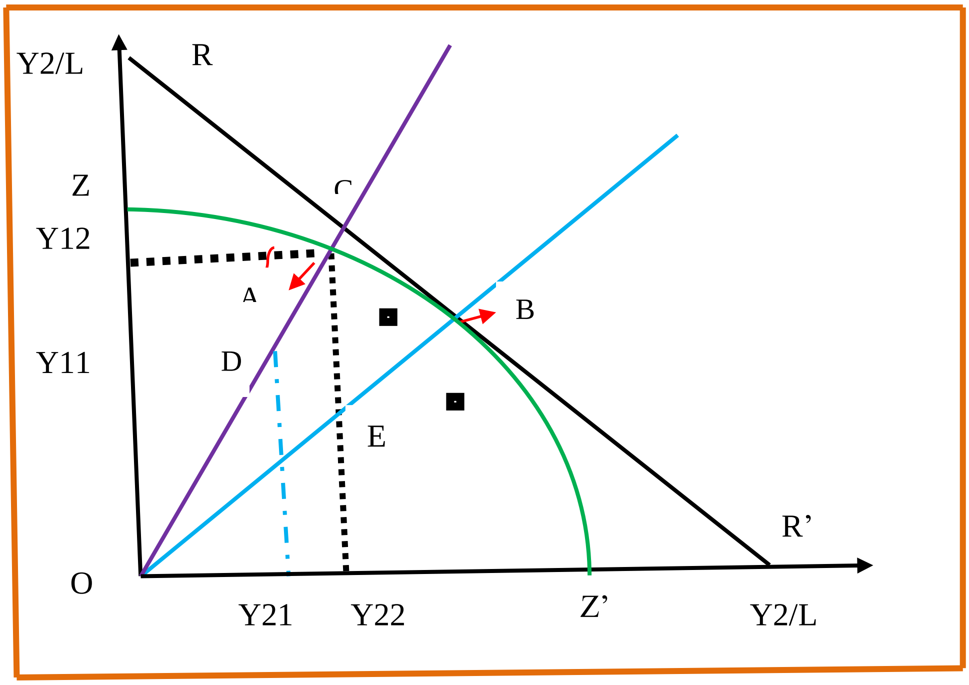

Figure 2: Output oriented illustration of technical and allocative efficiencies

As indicated on the production possibility curve (PPC), producers can be located either exactly on the PPC or below it. All producers on the curve have attained the maximum combination of Y1/L and Y2/L that can be produced given the input level and state of technology. But firms located below the curve are said to be inefficient. In this case, under the assumption of 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 Y1 and Y2 from Y11 to Y12 and from Y21 to Y22, respectively, without requiring extra inputs. This proportion (Y22 - Y21)/Y22 which is equal to (Y12 - Y11)/Y12 are the level of technical inefficiency of firm D, and thus the technical efficiency of D is given by:

TE = (1-(Y12 - Y11)/Y12) =OD/OA………………….......................................1.3

If price information on outputs is available, one can draw the isorevenue line RR' and measure the level of allocative efficiency, which is given by the ratio:

$$AE = OA / OC \text{.........} 1.4$$

The point of tangency between the isorevenue lines RR' and the production possibility curve ZZ' (point B') represents economically efficient method of production, which is 100% technically and allocatively efficient. And the EE again define as the product of TE and AE calculated as, $EE = \frac{OD}{OA} * \frac{OA}{OC} = \frac{OC}{OD} \ldots \ldots \ldots 1.5$

According to Coelli, *et al*. (1998) it is necessary to select orientation from input oriented or output oriented approach. Input oriented measure of efficiency was applied in this study. Because smallholder farmers in the study area have more control over inputs than outputs. This means that smallholder farmers have certain possibility to use minimum input combination to produce the given level of rice output than maximizing output from the existing level of input since there is uncertainty in agricultural productivity. Besides, it is pointed out that constant return to scale is only appropriated when all firms are operating at optimal scale. However, it is not possible to hold this assumption in agriculture in the study areas, because smallholder farmers face constraints.

2.1.3. Methods of efficiency measurements

Efficient frontier represents set of maximum output (potential output) for a given set of scarce resource and risk associated with it Farrell (1957). In order to measure efficiency we must construct efficient frontier. Two main approaches used to construct efficiency frontiers are parametric and non parametric approaches (Farrell, 1957; Charnes *et al*., 1978; Coelli *et al*., 2002 and Fried *et al*., 2008).

2.1.3.1. Non-parametric method

In this approach, estimation methods are based on envelopment techniques, free disposal hull which is developed by (Deprins *et al*., 2006) and data envelopment analysis which is developed by Farrell (1957). In both methods the estimation of EE is based on linear programming and consists of estimating a production frontier through a convex envelope curve formed by line segments joining observed efficient production units. DEA has the advantage of not imposing a priori-parametric restriction on the underlying technology. (Charnes *et al*., 1978).

The most commonly used non-parametric methods are Data Envelopment Analysis (DEA) and the more general Free Disposal Hull. DEA is a relatively new technique developed in operation research and management science over the last few decades. It is used for measuring productive efficiency only on observed input output data of firms and does not require any data on input prices. It is a mathematical programming approach used for considering optimum solution relative to individual units or firms rather than assuming that a solution applies to each DMU (Coelli, 1996).

The efficiency of an organization is calculated relative to the group's observed best practice. However, this method has disadvantage over: firstly, one cannot test for the best specification; secondly, it does not take measurement errors and random effects into account; thirdly, the number of efficient firms on the frontier tends to increase with the number of inputs and output variables and fourthly, results are sensitive to the selection of inputs.

2.1.3.2. Parametric approach

The stochastic frontier production function estimation would depend on this approach. It was independently and simultaneously proposed by Aigner *et al*. (1977) and Meeusen and Broeck (1977). The parametric approaches undertake to estimate the efficiency scores by estimating an efficient frontier. Thus, the difference between parametric and non-parametric approach is that while non-parametric approaches try to calculate the efficiency scores directly without estimating any frontier, the parametric model estimates the efficient frontier by estimating the parameters of frontier, and then measures the distance of observed input-output data to the estimated frontier.

There are priori assumptions made on the functional form of the production function and the distribution of the efficiency terms. The method consists of specifying and estimating a parametric production function representing the best available technology (Coelli *et al.*, 2002). The use of the functional forms of the production function such as the Cobb-Douglas and the Translog models are common. Depending on the treatment of deviations of an observation from a frontier, the estimated frontier can be either deterministic or stochastic. This Parametric approach is naturally subdivided into deterministic and stochastic models.

Deterministic frontier model: Deterministic regression attributes all deviations to inefficiency while stochastic assumes that part of the deviation from frontier is due to random errors (Coelli *et al.*, 2002). Aigner and Chu (1968) were the first researchers to estimate a deterministic frontier production function using Cobb-Douglas production function. They argued that, within a given industry, firms might differ from each other in their production processes, due to certain technical parameters in the industry, due to differences in scales of operation or due to organizational structures. Under this assumption, they considered a Cobb-Douglas production function, with an empirical frontier production model such as:

$Q_i \leq f(X_i)$ ………………………………………………………………………….….1.6

This inequality defines a production relationship between inputs, X_i and output Q_i, in which for any given x, the observed value of Q_i must be less or equal to f(X_i). Since the theoretical production function is an ideal (the frontier of efficient production), any non-zero disturbance is considered the result of inefficiency, which must have a negative effect on production function:

$Q_i = f(X_i; \beta) - \cup_i$ …..………………………………………….….….……..….1.7

Using natural logarithms, the model becomes:

$lnQ_i = \beta_0 + lnX_i\beta - \cup_i$ ……….………………….………….……………..….1.8

Where: lnQ_i is the natural logarithm of the output of the i^th^ firm; lnX_i is the natural logarithms of inputs; β is a column vector of the unknown parameters to be estimated; $\cup_i$ is a non-negative random variable associated with inefficiency, representing the shortfall of actual output from its maximum possible value. The limitation of this model is that, it treats random components (like measurement error, bad weather, etc) as part of inefficiency. Coelli (1995) argues that one of the criticisms of the deterministic approach is that no account is taken of the possible influences of measurement errors and other noises up on the shape and positioning of the estimated frontier. Normally deterministic production frontier can be estimated using linear programming or econometric techniques such as Corrected Ordinary Least Square and Modified Ordinary Least Squares (Kumbhakar and Lovell, 2000).

Stochastic frontier model: The stochastic frontier model was independently proposed by Aigner *et al.* (1977) and Meeusen and Broeck (1977). The model can be given as:

$$y_i = f(X_i.\beta) + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.9$$

Where: - y_i = The output for the ith sample farmer, X_i=A (1 × K) vector whose values are functions of inputs and explanatory variables for the ith farmer, $f(\,)$ is the appropriate functional form and β (K × 1) vector of unknown production parameters to be estimated ε_i is the composed error term, which equal, $V_i - U_i$, V_i symmetric component and permits a random variation in output due to factors such as weather, omitted variables and other exogenous shocks. It is assumed to be independently and identically distributed with,$v_{i\sim}N(0, \delta_v^2)$ while, the inefficacy effect U_i= non-negative unobservabl associated with the inefficiency of production such that for a given technology and levels of inputs.

The technical efficiency of a farmer, which can be predicted using the frontier program, which calculates the maximum likelihood estimators, is between 0 and 1 and is inversely related to the level of the technical inefficiency effect. For instance, if output is measured in logarithms, the farm specific technical efficiency can be estimated as:

$$TE = \frac{Y_i}{Y_i^*} = \frac{\exp(Xi\beta + Vi - Ui)}{\exp(Xi\beta + Vi)} = \exp(-Ui) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, $Y_i^* = \exp(X_i\beta + V_i)$ the frontier output for a sample data of 148 farmers.

Y_i = denotes output of rice produced by the ith farmer,

X_i = is (1×k) row vector with the first element equal to 1, of input quantity used by the ith farmer for the production of rice, β = ($\beta_{0,}\beta_1, \beta_2, \beta_3, \beta_4 \ldots\ldots \beta_k$) is (1×k) column vector of unknown parameters to be estimated,

U_i= is a non-negative random variable associated with technical inefficiency of the ith farmer for the rice production,

V_i = is random error term of the model which capture random shock of the production of rice in the ith farmer and i = 1, 2, 3… n is number of samples in a population.

U_i in this case is unobservable, so as exp $^{(-Ui)}$. However, Coelli *et al.* (1998) have indicated that the best predictor of exp $^{(-Ui)}$ assuming half-normal distribution for U_i is:

$$E\left[\frac{\exp(-Ui)}{\epsilon i}\right] = \frac{1-\Phi(\sigma\forall + \gamma\varepsilon i/\delta\forall}{1-\Phi(\gamma\epsilon i/\sigma\forall)} \exp(\gamma\varepsilon i + \delta\forall^2/2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.1)$$

Where: - $\delta\forall = \sqrt{\gamma(1-\gamma)}\ \delta s^2$

γ = gamma and εi = maximum likelihood residual ($\varepsilon_i = \ln y_i - X_i\beta$)

Φ = Density functions of standard normal random variable.

2.2. Empirical literature on efficiencies

Under this sub-section, empirical efficiency studies from abroad and in Ethiopia were reviewed consecutively.

2.2.1. Empirical Studies on efficiency from abroad

Various efficiency studies have been conducted in both developed and developing countries using stochastic frontier analysis (SFA) method. For instance, Heriqbaldi1*et al*. (2014) used SFA to estimate TE of rice production in Indonesia. They found that, the Overall, average TE was 77%, indicating that the average farm produced only 77% of the maximum attainable output for a given input levels. This implies that there is considerable possibility for enhancing TE and productivity as well as the overall rice output. It was also found that factors like land size, income and source of funding were influential determinants of TE.

An attempt has been made by Samarpitha *et al*. (2016) to estimate the TE, AE and EE of rice producer farmers in Nalgonda district of Telangana state India, using stochastic frontier approach (Cobb-Douglas). The mean TE, AE and EE were found to be 92.44, 81.68 and 88.36%, respectively. The results revealed that 63 and 76 % of technical and economic inefficiencies respectively were largely within the control of individual farmers. Human labor was found to be the major determinant of rice productivity in the region. According to them, one percent increase in the prices of human labor, machine labor and fertilizers was found to reduce the profits by 0.25, 0.46 and 0.18 %, respectively at their mean levels. Education level of a farmer, experience in rice cultivation, membership in cooperative society and access to credit were the most influential determinants of TE. The mean TE values of greater than 90% for majority (55.83%) of the rice farmers indicated that there was little scope for improving the efficiencies of these farmers with the existing technology as the farmers were already operating near the frontier. Hence new location-specific technologies should be developed and transferred to farmers. However, for farms operating at lower levels of efficiency, sufficient potential also exists for improving the productivity of rice by proper management and allocation of the existing resources and technology.

Magreta (2011), study, EE of rice production in smallholder irrigation schemes in Southern Malawi. He was used a parametric frontier approach to analyze EE of smallholder rice producer farmers. The study used a Trans-log stochastic production function and Trans-log cost frontier to analyze TE and EE respectively. The results showed that an average TE, AE and EE levels were 65%, 59% and 53%, respectively. This suggests that farmers have a rice yield potential of 35% to be exploited. The average EE level showed that farmers could raise their rice production by 47% by adjusting input use. Soil fertility status, access to credit, household size and farmers experience were the factors that influence the efficiency levels of smallholder rice producers. It was recommended that for improved efficiency levels there is need for better policies and strategies that address input and output markets. Furthermore, farmer groups or associations can play a great role in ensuring that farmers get relevant technical advice, credit access as well as learn and share knowledge from each other.

Binam *et al.* (2016) conducted a study on TE of small-scale rice farmers in West region of Cameroon using SFA. The result indicated that farm size and labor have significant effects on the output of rice. This indicates that, increases in farm size and labor use lead to increases in rice output. In contrast, fertilizer and extension contact were affects the output of rice negatively. The mean TE for small-scale rice farmers was 82%. This suggests that TE could be increased by 18% given the current level of technology if the available resources are efficiently utilized. He recommended that, Training aimed at fertilizer application and credit use by small-scale farmers should be frequently organized in the studied area.

Galawat and Yabe (2012) attempted to investigate technical, allocative, and economic efficiency in rice production in Brunei Darussalam, Japan using SFA. Their empirical result showed that the means of TE, AE and EE were 76.3%, 65.7% and 53.1%, respectively. This suggests that there is a considerable room for improvements in increasing rice productivity through better use of available resources given the state of technology. This study indicated that improvements in irrigation and soil fertility might reduce overall inefficiencies among rice farmers in Brunei.

Factors like farm size, age, gender, experience and training had a significant impact in increasing/decreasing farmer's efficiency. Another noteworthy variable was that, farmers who joined cooperatives or associations are more efficient than farmers who do not.

A study was conducted by Taraka *et al*. (2012) on estimation of TE of rice producing farmers in the central region of Thailand using SFA specified as a Translog production function. They found that TE ranged from 49.69 to 97.17%, with a mean of 85.35%. Gender, farming experience, good agricultural practices and cropping intensity were found to contribute positively toward farm TE. Latterly it was recommended that, agricultural extension officers should organize knowledge, experience exchange between successful farmers, and promote the use of certified seeds to improve farm efficiency and farmers' income.

Kea *et al*. (2016) used SFA particularly Translog production functional form to analysis TE and its determinants of rice production in Cambodia. Their finding indicated that the overall average efficiency of rice production was 78.4%, which implies that there is stillroom to further improve TE given the same level of inputs and technology. More importantly, the findings revealed that irrigation, production techniques, amount of agricultural supporting staff and fertilizer were the most important influencing factors on TE of rice production in Cambodia. This study was divergence with Binam *et al*. (2016) finding on the effect of fertilizer on rice TE. According to Binam *et al*. (2016) fertilizer has negative impact on TE of rice production. They justified that increases in quantity of fertilizer lead to decreases in rice output. This might be, due to knowledge gap among the farmers on the application of fertilizer.

A study conducted by Wakili (2012) to estimate TE of sorghum production in Hong Local government area of Adamana State, Nigeria used SFA and he found that, the mean technical efficiency of sorghum was approximately 73%. According to this research, major factors like, education levels of the farmers, household size, contact with extension agents and experience in sorghum farming were significantly explaining TE. Family labor, membership to association and herbicide were not significant. It was concluded that estimation of efficiency was of vital importance since increased production is directly related to production efficiency.

2.2.2. Review of empirical Studies on efficiency in Ethiopia

Different efficiency studies also have been conducted in Ethiopia using stochastic frontier analysis (SFA) method. For example, a study by Mustefa *et al*. (2017) on EE in maize production in Ilu Ababor zone, Ethiopia, using SFA with Cobb-Douglas production function to estimate the efficiencies level and Tobit model was used to identify determinants that affect efficiency levels of the sample farmers. Their finding showed that the mean TE, AE and EE were 81.78%, 37.45% and 30.62%, respectively. The result indicate that education level of the sample household was the most important factor that found to be statistically significant to affect the level of TE,AE and EE all together. Whereas, land fragmentation and soil fertility were the major factors that affect the level of TE. Besides, land fragmentation, livestock ownership and frequency of extension contact were important factors these affect AE of farmers in the study area. The results also further revealed that extension contact was significantly affecting EE. Finally, they recommended that ,in order to increase EE level in maize production, all concerned bodies and stakeholders should give due attention in determining coping up mechanism to significant determinants.

Finding by Bealu *et al*. (2013) on factors affecting EE in maize production: the Case of Boricha *Woreda* in Sidama Zone, Southern Ethiopia, was also used a stochastic frontier model with Cobb-Douglas production function. The analysis result was showed that, the mean technical and allocative efficiencies were 72 and 70 %, respectively while the mean EE was 53 %. Furthermore, descriptive statistics and a two-limit Tobit regression models were employed. The estimated result of Cobb-Douglas production function was positively influenced by seed, labor, oxen, farm size, DAP and Urea fertilizers. Similarly, a Tobit model revealed that EE was positively and significantly affected by education, trainings, membership to cooperatives, utilization of credit, and family size whereas variables such as age distance to extension center and market, livestock and off-farm income affected it negatively. Finally they were, recommended the importance of policies targeting training, membership to cooperatives development of markets, roads and education of smallholder maize producers that would promote EE of maize producers.

Another study on technical, allocative and economic efficiency of maize production conducted by Musa *et al.* (2015) in central rift valley of Ethiopia. According to this mean technical, allocative and economic efficiencies were 84.87%, 37.47% and 31.62%, respectively. Among factors, they hypothesized to determine the level of efficiency scores, education was found to determine allocative and economic efficiencies of farmers positively while the frequency of extension contact had a positive relationship with TE and it was negatively related to both allocative and economic efficiencies. Credit was also found to influence technical and economic efficiencies positively and distance to market affected TE negatively. It was summarized that there was a room to increase the efficiency of maize producers in the study area.

Analysis of EE estimation and identification of their determinants in mixed crop and market-driven vegetable production systems in two districts of eastern Ethiopia were undertaken by Jema (2008). The study used both DEA and SFA methods and the result indicate that the mean TE, AE and EE were 91, 60 and 56%, respectively. Based on the comparison result of the two production systems there were a significant economic inefficiency in the study area. He also revealed that variables such as farm size, education, extension visit, asset value, family size, farm distance, level of consumer spending and large family size were determinants of TE. The study suggested that a lower EE scores for market oriented vegetable production was mainly attributable to limited access to capital markets, high consumer spending and large family size.

According to (Sisay *et al.*, 2015) technical, allocative, and economic efficiency study among smallholder maize farmers in Southwestern Ethiopia, they were used parametric stochastic frontier production function (Cobb-Douglas) to estimates EE and two-limit Tobit regression model for inefficiency effects. The results show that the mean TE, AE and EE score was found to be 62.3, 57.1 and 39%, respectively, indicating a substantial level of inefficiency in maize production. The result depicted that important factors that affected TE, AE and EE were number of family size, level of education, extension service, cooperative membership, farm size, livestock holding and use of mobile. Finally, it was recommended that government should motivate and mobilize the youth in agricultural activities, invest in the provision of basic education and facilitate the necessary materials, strengthen the existing agricultural extension system, Organize non-member farmers in cooperative association and attention to enhance the efficiency of farmers with large land holding sizes were suggested.

Solomon (2012) undertook a study on EE of wheat seed production in West Gojjam zone of Amhara Region. Stochastic production frontier model was used to estimate TE, AE and EE levels, where as Tobit model was used to identify factors affecting efficiency level. The results indicated that the mean technical, allocative and economic efficiencies of sample households were 79.9%, 47.7% and 37.3%, respectively. Results of the Tobit model revealed that interest in wheat seed business and total income positively and significantly affect TE while total expenditure has a negative and significant effect. Education level and livestock ownership have a significant positive impact on AE and EE while participation in sharecropping and total cultivated land have a significant negative effect on AE and EE, respectively. According to him, the mean TE levels further suggested that wheat seed farmers in the study area could increase their production by 20% without using extra inputs. Alternatively, farmers can reduce, on average, their cost of production by 52.3% without reducing the existing level of output.

A study on efficiency measurement and their differential in Wheat Production the Case of smallholder farmers in South Wollo by Hassen (2016) SFA were applied in his investigation. The results indicate that the average TE was 78%, while return to scale was 1.17%, implying that farmers were operating at an increasing return to scale. The socio-economic variables that exercised important role for variations in TE were age, education, farm size and livestock holding in TLU, number of oxen holding, access to irrigation and access to credit. Nevertheless, participation on off farm income, and interaction of off farm income and education was found to decrease efficiency significantly among farm household.

Wudineh and Endrias (2016) used Stochastic production frontier model specifically Translog functional form with a one-step approach to estimate the efficiency level of smallholder wheat producer farmers in Welmera district, Central Oromia. They found that the mean TE was 57%.They also reported that factors such as sex, age and education level of the household head, livestock holding, group membership, farm size, fragmentation, tenure status and investment in inorganic fertilizers affect efficiency positively. According to them, there was an opportunity to improve TE among the farmers by 43% through gender-sensitive agricultural intervention, group approach extension and attention to farmers' education, scaling out of best farm practices. Finally, it was recommends that further empirical work to be conducted on the effects of infrastructures like roads on TE using a large number observation.

A study conducted by Wondimu and Hassen (2014) was used SFA to determined TE in maize production in Dhidhessa District of Illuababora Zone, Ethiopia. They investigate that the average TE was 86%, while return to scale was 0.96.The socio-economic variables that exercised important role for variations in TE were age, education, improved seed, training on maize production and labor availability in the household. Nevertheless, participation on off farm income, interaction of off farm income and education, distance to market, and number of livestock was found to decrease efficiency significantly among farm household.

Tadesse *et al*. (2016) found that except manure all the variables in the Cobb-Douglass stochastic frontier model, which includes; land, fertilizer, oxen, seed and labor are found to be positively and significantly related to rice production. The average TE score predicted from the estimated Cobb-Douglas stochastic frontier production function was found to be 77.2%, implying that there was possibility to rice yield increment by improving the resource use efficiency of the households. As they reported, provision of extension service, training on rice product improvement, experience on rice farming, agrochemical and education tend to be positively and significantly related to TE while household size is negatively and significantly related with TE.

2.2.3. Summary of efficiency Studies

In today's' world there is a growing body of research on efficiency using different approaches, in agriculture. Economic efficiencies studies have been conducted on different crops such as Maize, Wheat, *Teff*, Sorghum, Rice, Barley etc. Most of these studies however have reported low to moderate average TE, AE and EE as presented in the summary (table1) below. In addition, there are many factors had been explained these influence in TE, AE and EE. Among the factors given priority includes, farmers' education levels, farmers' access to improved technologies, input cost, access to extension services, credit access, Household size, participation on off/none farm income and size of land etc. According to various studies reviewed (table1), most of the researchers used SFA in agriculture efficiency studies than DEA. Even though Data

Envelopment Analysis (DEA) or nonparametric approach has the power of accommodating multiple output and inputs in efficiencies analysis, it fails to take into consideration the possible impact of random shock like measurement error and other noise in the data (Coelli, 1995).Another disadvantage is that it is less robust to outliers and extreme values However, a large number of empirical studies have extended and applied the DEA technology in the study of efficiency worldwide (Chimai, 2011).

On the other hand, the stochastic frontier does not accommodate multiple input and output. It is also more likely to be influenced by misspecification issues. However, the fact that it incorporates stochastic component into a model increased its applicability in the analysis of EE of agricultural productions. Thus, for this study the stochastic frontier analysis was used.

Table 1. Summary of reviewed efficiency researches done in different countries

No	Author	Year	Approach	Functional form	Country	Average efficiency%		
						TE	AE	EE
1	Mustefa *et al*.,	2017	SFA	Cobb-Douglas	Ethiopia	82	38	31
2	Bealu *et al.*,	2013	SFA	Cobb-Douglas	Ethiopia	72	70	53
3	Musa *et al.*,	2015	SFA	Cobb-Douglas	Ethiopia	85	38	32
4	Jema	2008	DEA&SFA	Cobb-Douglas	Ethiopia	91	60	56
5	Sisay *et al*.,	2015	SFA	Cobb-Douglas	Ethiopia	62	57	39
6	Solomon	2012	SFA	Cobb-Douglas	Ethiopia	80	48	37
7	Samarpitha *et al*.	2016	SFA	Cobb-Douglas	India	92	82	88
8	Magreta	2011	SFA	Trans-Log	Malawi	65	59	53
9	Hassen	2016	SFA	Cobb-Douglas	Ethiopia	78	-	-
10	Wudineh& Endrias	2016	SFA	Trans-Log	Ethiopia	57	-	-
11	Wondimu&Hassen	2014	SFA	Cobb-Douglas	Ethiopia	86	-	-
12	Tadesse *et al*.,	2016	SFA	Cobb-Douglas	Ethiopia	77	-	-
13	Heriqbaldi1*et al*.	2014	SFA	Trans-Log	Indonesia	77	-	-
14	Binam *et al.*	2016	SFA	Cobb-Douglas	Cameroon	82	-	-
15	Taraka *et al*.	2012	SFA	Trans-Log	Thailand	85	-	-
16	Kea *et al*.	2016	SFA	Trans-Log	Cambodia	78	-	-
17	Wakili	2012	SFA	Cobb-Douglas	Nigeria	73	-	-
18	Galawat & Yabe	2012	SFA	Cobb-Douglas	Japan	76	66	53

Source: Own review

2.3. Conceptual frame work of the study

Raising agricultural productivity depends critically on improvement of efficiency in production, development and dissemination of cost effective productivity-enhancing technologies, which leads to directly by raising production levels (Kydd *et al*., 2001). Increasing agricultural productivity has a number of advantages. First, facilitates the flow of resources from one sector to another and contributes to economic growth. Second, a higher level of agricultural productivity results in lower food prices for consumers and a rise in income of producers that increases the welfare of the society and thereby enhancing the economic growth of the country. Third, agricultural productivity growth also improves the competitive position of the sector.

Efficiency in production is assumed to be affected by a wide range of factors. The host of socio-economic and institutional factors (Jema, 2008) determined efficiency of production. These factors directly/indirectly affect the quality of management of the farm's operator and believed to have effect on the level of economic efficiencies of farms.

From the extensive reviews, these various factors can be grouped into the following four broad categories: Demographic, socioeconomic, farm and institutional characteristics. The factors related to demographic characteristics include age, sex and family size. The factors related to the socioeconomic characteristics include education level, livestock holding and non-farm activities etc. The factors related to farm characteristics include the number of plots (fragmentation) and plots distance. The institutional factors include; access to credit, extension contact and cooperative membership.

Figure 3 summarizes the interaction between various factors that are considered to have a various degree and direction of effect on the level of technical, allocative and economic efficiencies of rice production. This scenario is represented in a pictorial form as a conceptual framework to guide this study.

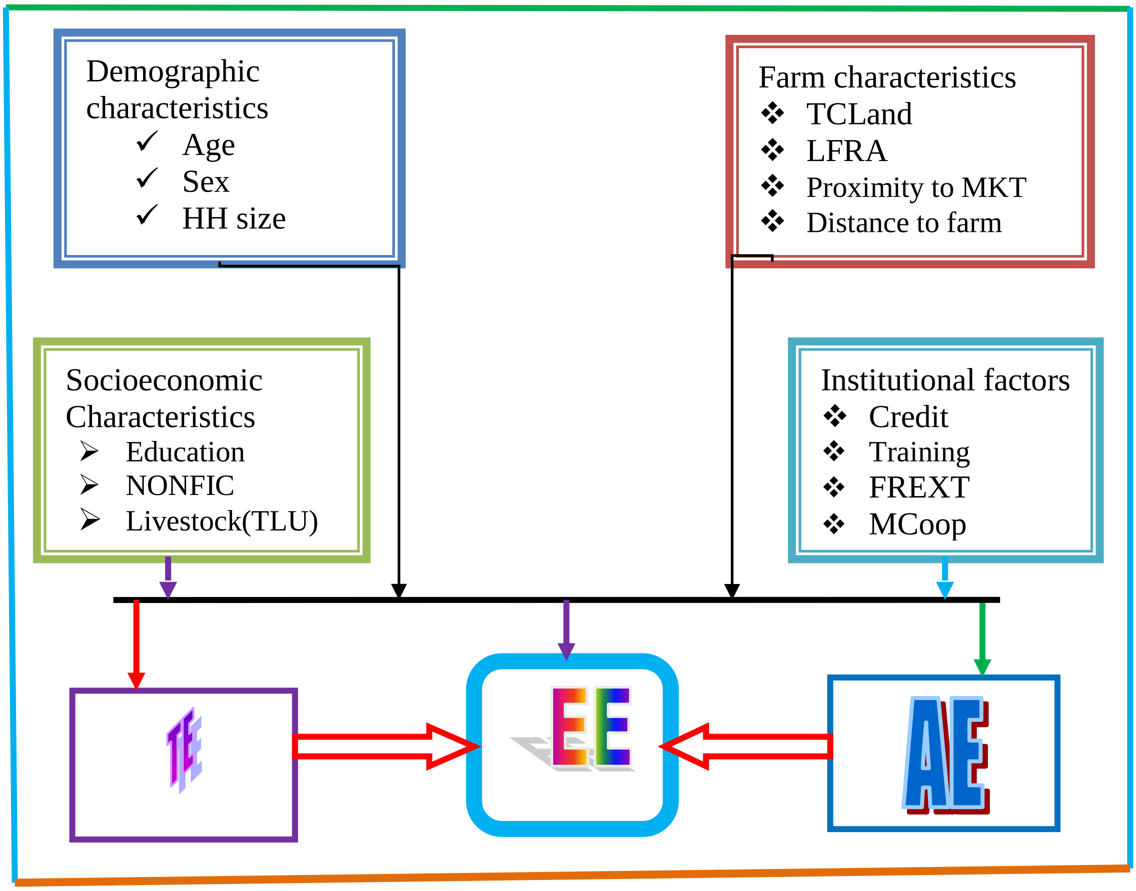

Figure 3: Conceptual framework of economic efficiency

Source: own conceptualization from different literature review

3. RESEARCH METHODOLOGY

In this section, the physical feature of the study area, types and sources of data, sampling design, methods of data collection and methods of data analysis and definitions of variables hypothesized are presented.

3.1. Description of the Study Area

This study was conducted in Guraferda woreda, in SNNPR, in Bench Maji zone. The woreda center is Biftu, which is at about 561 km away from south west of Addis Ababa and 42 km from the zonal capital Mizan. It covers a total area of 228,281.25ha. From these, 15160, 1500,500,126000, 85061.25 and 60 ha are farming land, grazing land, residential area, forestland, others/bushes and nonfarm and swampy areas, respectively. The worada is bordered on the south by Bero, on the west and north by Gambela region, on the northeast by Sheko, on the east by Debub Bench and on the southeast by Meinit Shasha. There are 27 *Kebeles* in the woreda (GWAO, 2018).

According to (CSA, 2013) the total population of the woreda in the year 2014 was estimated to be 43,137. Out of the total population, 54.42% and 45.58% are male and female, respectively. Geographically, it is positioned between 6049‘‘33”-6058‘‘06”N latitude and 35007‘‘03”-35025‘‘02”E longitude (Belay, 2009).

Agro-climatic zones: The agro-climatic zones Guraferda are lowland (Moist Qolla) and (Waynadaga), which constitute 78.25% and 21.75%, respectively. The altitude ranges from 700 to 1995 meters above sea level (Belay, 2009). The mean annual rainfall of the study area is between 1500-2400mm. The area receives highest rainfall in October and the lowest in February. In this area, the peak monthly temperature is maintained in months of March and October. Average monthly temperature of this woreda is 29.5^{o}C (GWAO, 2018).

Rice production trend and socio-economic activities of the woreda: The majority (75%) of the people in the woreda depend on rice production (GWAO, 2018). The woreda is predominantly plough-based agriculture dominated by cash crops, like coffee sesame and rice. The first three major products of the woreda are coffee, rice and maize. The type of local rice variety named as X-jegena was widely used by majority of farmers in the woreda. In addition, few farmers use NERICA4 and SUPERICA. NERICAs, varieties, are especially have been under dissemination and expansion in different agro-ecologies of the country, from lowlands of 750 m to areas of about 2000 m elevations by different governmental and non-governmental organizations (MoARD, 2014).

Perennial cash crops such as coffee and fruits being intensified in both resettlement schemes and *enset* is planted in the state-organized resettlement sites. Among the annual crops, rice covers the bulk of production. Guraferda become one of the surplus crop producers in the region. Besides crop production, the farmers of the woreda raise livestock for their farm and for their milk consumption (Abeje, 2011).

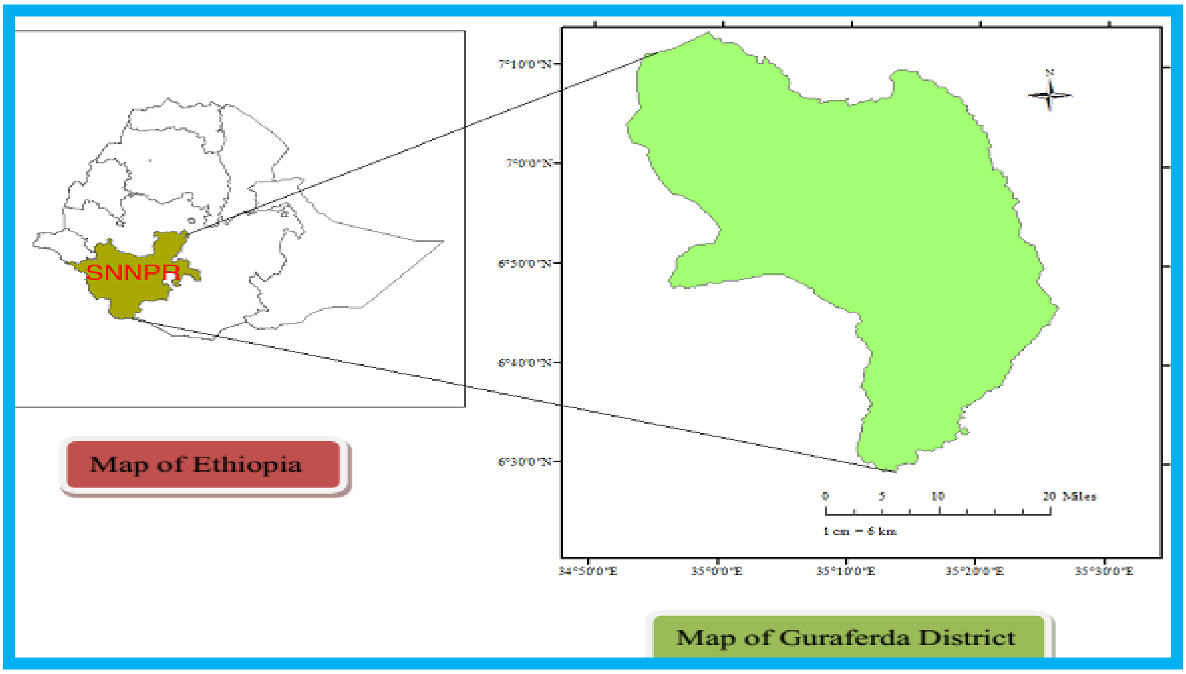

Figure 4: Geographical location of the study area

3.2. Type and source of data

To analyze economic efficiency of rice production in Guraferda woreda, the qualitative and quantitative, data was collected from both primary and secondary sources.

Before selection, types of questionnaires it is rational to describe the nature and applied area of each questionnaire accordingly. Structured questionnaire is one of the three types of questionnaires; it consists of items or questions with totally pre-categorized response options. It is a rigid type. It can be yes/no, or multiple-choice, or Linker scale, or other rating scale format in nature and mostly used for quantitative studies.

The second type of questionnaire is unstructured. Which is totally open ended questions and the respondents are not restricted to a fixed choice. This is usually used in qualitative studies to explore the opinion of the interviewees. It could be applied during in-depth interview and focus group discussion. Semi-structured questionnaire is the third types, which is in between the two, which is fixed to some extent (open and close ended) but there is a room for the interviewees to give additional answer or explanations for the question and it widely used in qualitative study (Synodinos, 2003). As a result, this study has more quantitative nature, structured questionnaire interviews was used to collect primary data from smallholder rice producing farmer.

Information on demographic, institutional, farm characteristics and socio-economic factors and price data were collected as a source of primary data. Similarly, the amount and cost of inputs used such as seed, labor, fertilizers, land, oxen power, herbicide and amount of outputs obtained were collected. Before starting the actual data collection, some preliminary information about the overall farming system of the woreda was accessed through informal survey. HH, who, are produce rice during the period 2017/18 in woreda was considered as the sampling unit of the study.

The secondary sources of data related to rice production was collected to clarify and support analysis and interpretation of primary data. Information like, climatic conditions of the woreda such as temperatures, rainfall and socio-economic activities of the households were gathered. This information was collected from relevant publications, which included the project baseline survey report of, MoARD, CSA, FAO, ATA, FDRE, GWAO and EUCORD conducted in recent time, reports of similar studies, information documented at various office levels of Agricultural research institution and different books were reviewed.

3.3. Method of data collection

To carry out data collection, structured questionnaire was implemented by enumerators who were recruited through an interview just before the start of the survey exercise. Then the successful enumerators were trained on how to administer the questionnaires, the nature and content of the questionnaire and any ambiguities were clarified. Before data collection, the questionnaires were pre-tested on some rice producer farmers to evaluate the appropriateness of the design, clarity and interpretation of the questions, relevance of the questions, to make sure important issues have not been left out and to estimate time required for an interview. Subsequently, appropriate modifications and corrections made on the questionnaire. After necessary adjustments are made, the pre-tested questionnaires were administered with the assistance of well-trained enumerators in the study area and the whole exercise of data collection was completed in three weeks.

3.4. Sampling technique and sample size determination

Combinations of two stage random and purposive sampling techniques were employed to draw an appropriate sample. Guraferda woreda was selected purposively for its volume of production, area coverage and number of rice producers. Due to the reason that, this study focused on efficiency of rice production, rice producer *kebeles* were the major targets in sample selection. In this woreda only 18 rural *kebeles* were rice producers out of which six *kebeles* were selected randomly in the first stage. In the second stage, a total of 148 sample rice producer household heads (HHs) were selected randomly using probability proportional to size (Table2).

A simplified formula provided by Yamane (Yamane, 1967) was used to determine sample size.

$$n = \frac{N}{1 + N(e)^2} \quad \ldots\ldots\ldots \quad 2.2$$

Where n = sample size

N = Total number of rice producer household heads

e = level of precision (8%)

Table 2. Distribution of sample household heads across sample *kebeles*

Name of sample *kebeles*	No. of rice producing farmers	Sample size
Alenga	548	26
Semerta	388	18
Kuja	718	34
Berji	434	20
Otowa	563	26
Gabiqa	517	24
Total	3,168	148

Source :(GWAO, 2018)

3.5. Method of data analysis

To address the objectives of the study, both descriptive statistics and econometric models were used to analyze the data. Descriptive statistics such as mean, standard deviation, frequency and percentage values were used to support econometric model result and to describe the farming practice in the study area. From the econometric analysis SFA specifically Cobb-Douglass production function was used based on the result of GLR test in chapter four, to estimate the level of TE, AE and EE and Two-limit Tobit model was used to identify factors that affect the efficiency level of smallholder rice producer farmers.

3.5.1. Specification of econometric models

3.5.1.1. Efficiency measurement

As mentioned earlier in chapter two, unlike DEA, the stochastic frontier approach enables us to test for the best specification and it takes measurement error and random effects into account. Therefore stochastic frontiers method was used in this study. Because, uncertainty of agricultural production. Which is attributable to climatic hazards, plant pathology and insect pests, on the one hand and management inefficiencies on the other. 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 every farm (Anton *et al*., 2012).

Following Aigner *et al.* (1977) and Meeusen and Broeck (1977), the general functional form of stochastic frontier model for this study was specified as follows:

$$y_i = f(X_i.\beta) + \varepsilon_i \qquad \ldots 2.3$$

Where: - y_i = The output for the ith sample farmer =1, 2, 3… n, X_i = vector whose values are functions of inputs and explanatory variables for the ith farmer, $f(\,)$ is the appropriate functional form and β vector of unknown production parameters to be estimated ε_i is the composed error term (V_i and U_i) and n = number of farmers involved in the survey.

3.5.2. Selection and estimation of empirical model

Cobb-Douglas and Translog functions have been the most widely used functional forms in most empirical production analysis studies. Each functional form has its own advantage and limitations. 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. It is widely used in the frontier production function studies (Hazarika and Subramanian, 1999).

In addition, due to its simplicity features, the Cobb-Douglas functional form has been commonly used in most empirical estimation of frontier models. This simplicity however, is associated with some restrictive features in that it assumes constant elasticity, constant return to scale for all farms and elasticity of substitution are equal to one (Coelli *et al*., 1998).

On the other hand, the Translog functional form imposes no restrictions upon returns to scale or substitution possibilities. However, the problem of degrees of freedom and multicollinearity is a serious problem in Translog production function (Coelli *et al*., 1998).

Moreover, several studies specifically farm efficiency studies (Solomon,2012; Wakili,2012; Bealu *et al.*,2013; Sisay *et al*.,2015; Musa *et al.*,2015; Binam *et al.*2016; Samarpitha *et al*.,2016; Tadesse *et al*.,2016 and Mustefa *et al*.,2017) used Cobb-Douglas functional form despite its limitations. The specific Cobb-Douglas production model estimated was given by:

$$Y_i = \beta_o * \prod_{i=1}^{n} X_i^{\beta_i} * e^{(V_i - U_i)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.4$$

Following the Aigner *et al*. (1977) and Meeusen and Broeck (1977) method of estimating a stochastic frontier production function (SFPF), with a Cobb-Douglas production function type by transforming (question 2.4) it into double log-linear form to ‘estimate the efficiency level in rice production of smallholder farmers in the study area, was specified as:

$$lny_i = In\beta_0 + \sum_{j=1}^{7} \beta_j \, lnx_{ij} + v_i - u_i, i = 1,2, \ldots n \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \ldots \ldots \ldots \ldots \ldots \ldots 2.5$$

Where: ln = the natural logarithm (in base e); Y = rice output in Qt; X_1= area covered with rice in ha; X_2 = family and hired labor input used in person-days; X_3=seed input applied in Kg; X_4= fertilizers (Dap and Urea) applied in Kg; X_6=oxen inputs used by the i^{th} farmer in pair of oxen-days and X_7=chemical (herbicide) in litter. β_0= level of rice output from ha of land at natural state (the intercept) and the other β_j = constitutes a vector of parameters to be estimated V_i, is a symmetric error term accounting for the deviation from the frontier because of factors which are beyond the control of the farmer and u_i , is a one sided error term accounting for the deviation because of inefficiency effects.

As a result, taking the advantages and disadvantages of both functional forms in to consideration the appropriate functional form that better fit the data was selected after testing the null hypotheses using the generalized likelihood ratio (GLR) test. The value of the GLR statistic to test the hypothesis that all interaction terms including the square root specification (in the Translog functional form) is equal to zero (H0 = β_{ij} = 0) was calculated as follow:

LR= -2[L (T*l*)-L (CD)] …………………………………………………………….2.6

Where: LR = Generalized log-likelihood ratio

L (T*l*) = Log-likelihood value of Translog

L (Cd) = Log-likelihood value of Cobb-Douglas

Then this value compared with the upper 5% point for the χ^2 distribution and decision was made based on the result.

Aigner *et al.* (1977) proposed the log likelihood function for the model in equation (2.5) assuming half normal distribution for the technical inefficiency effects (U_i).They expressed the likelihood function using λ parameterization, where λ is the ratio of the standard errors of the non-symmetric to symmetric error term (i.e. $\lambda = \frac{\delta u}{\delta v}$. However, there is an association between γ and λ. The reason is that λ could be any non-negative value while γ ranges from zero to one. According to Bravo and Pinheiro (1997) gamma (γ) calculated as,

$$\gamma = \frac{\lambda^2}{\lambda^2+1} \ldots \quad 2.7$$

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

Using the above estimated Cobb-Douglas production function in equation 2.5 estimation of TE for individual farms was predicted by obtaining the ratio of the observed production values to the corresponding estimated frontier values. The value achieves its maximum feasible value if and only if $TE_i = 1$ otherwise, $TE_i < 1$.The TE for the i^{th} farms can be computed as,

$$TE = \frac{\log y_i = \beta_0 + \sum_{j=1}^{5} \beta_j \log x_{ij} + v_i - u_i}{\log y_i = \beta_0 + \sum_{j=1}^{5} \beta_j \log x_{ij} + v_i} \ldots \quad 2.8$$

Sharma *et al*. (1999) suggests that the corresponding dual cost frontier of the Cobb-Douglas production functional from equation (2.3) can be rewritten as:

$$C_i = C(W_{i,} Y_i^*; \alpha) \ldots \quad 2.9$$

Where i refers to the i^{th} sample household; C_i is the minimum cost of production; $W_{i,}$denotes input prices; Y_i^* refers to farm output which is adjusted for noise and α's are parameters to be estimated. The economically efficient input vector of the i^{th} household X_{ie} is derived by applying Shepards' lemma (Arega and Rashid, 2006) and substituting the firms input prices and adjusted output level, a system of minimum cost input demand equation can be written below in question (3) as a derivation form as follow:

$$\frac{\partial C_i}{\partial W_n} = X_i e(W_{i,} Y_i^*; \alpha) \ldots \quad 3$$

Where n is the number of inputs used. The minimum cost is derived analytically from the production function, using the methodology used in Arega and Rashid (2006). Given input oriented function, the efficient cost function can be specified as,

$$Min \sum_{x} C = \sum_{j=1}^{7} X_J W_J \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

Sebject to $Y_i^* = \hat{A} \prod X_i^{\hat{B}_j}$

Wher $\hat{A} = \exp(\hat{B}_0)$

ω_J=input prices

$\hat{B}_0$= Parameter estimates of the stochastic production function and

Y_i^*=input oriented adjusted output level.

The following dual cost function is found by substituting the cost minimizing input quantities into equation 3.2.

$$C(Y_k^{i^*}, w) = HY_k^{i^*\mu} \Pi_n w_n^{\alpha_n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

$$\alpha_n = \mu \hat{B}_n, \mu = (\Sigma_n \hat{B}_{n)}^{-1}, H = \frac{1}{\mu}(\hat{A} \Pi_n \hat{B}_{n)}^{\beta_{n-\mu}} \ldots\ldots\ldots\ldots\ldots 3.3$$

EE for the i[th] farmer is derived by applying Shepard's Lemma and substituting the firms input price and adjusted output level into the resulting system of input demand equations.

$$\frac{\alpha C_i}{\alpha \omega_n} = X_i^e(\omega_i Y_i^{i^*}; \theta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.4$$

Where: Ө is the vector of parameters and n = 1, 2, 3…, N inputs. The observed, technically and economically efficient costs of production of the i[th] farm are then equal to $\omega_i' X_i$, $\omega_i' X_i^t$ and $\omega_i' X_i^t$; respectively. Those cost measures was used to compute technically and economically efficient indices of the i[th] farmer as follows:

$$\frac{\omega_i' X_i^t}{\omega_i' X_i} = \frac{Y_i}{Y_i^*} = TE \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.5$$

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

$$\frac{C^*}{C} = EE \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.6$$

Following Farrell (1957), the AE index can be derived from equations (3.5) and (3.6) as follows:

$$\frac{\mathrm{EE}}{\mathrm{TE}} = AE \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.7$$

3.5.2.1. Determinants of efficiency

To analyze the effect of demographic, socioeconomic, farm attributes and institutional variables on technical, allocative and economic efficiencies a second stage procedure was used, where the efficiency scores were regressed on selected explanatory variables using two-limit Tobit model. This model is best suited for such analysis because of the nature of the dependent variable (efficiency scores), which takes values between 0 and 1 and yield the consistent estimates for unknown parameter vector (Maddala, 1983). Estimation with (OLS) regression of the efficiency score would lead to a biased parameter estimate since OLS regression assumes normal and homoskedastic distribution of the disturbance and the dependent variable (Greene, 2004).

Following Maddala (1983) the two-limit Tobit model can be specified as,

$$Y^*_{i\,(TE,AE,EE)} = \delta_0 + \sum_{j=1}^{13} \delta_j' \, \mathrm{X}_{j\mathrm{K}} + \mu_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.8$$

Where Y_i^* is the latent variable representing the efficiency scores,δ_0, $\delta_1, \ldots, \delta_{13}$ are parameters to be estimated,X_j represent the demographic, socio economic farm and institutional factors that affect efficiency level and μ_i= an error term that is independently and normally distributed with mean zero and variance (δ^2 ~IN (0, δ^2)). Farm-specific efficiency scores for the smallholder rice producers range between zero and one. As a result, two-limit Tobit model can be presented as follow.

$$Y_i = \begin{cases} 1, if\ Y_i^* \geq 1 \\ Y_i^*\ \ if\ 0 < Y_i^* < 1 \\ 0, if\ Y_i^* \leq 0 \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.9$$

Following Maddala (1983), the likelihood function of this model is specified as

$$\mathrm{L}(\beta, \delta | \mathrm{y_j}, \mathrm{X_j}, \mathrm{L_{1j,}} \mathrm{L_{2j}}) = \Pi_{\mathrm{y_{j-L1j}}} \Phi\left(\frac{\mathrm{L_{1j-\beta' x_j}}}{\delta}\right) \Pi_{\mathrm{y_{j-2j}}} \Phi\left(\frac{\mathrm{y_{i-\beta' x_j}}}{\delta}\right) \Pi_{\mathrm{y_{j-y_j^*}}} \Phi\left(\frac{\mathrm{L_{2j-\beta' x_j}}}{\delta}\right) \ldots\ldots\ldots 4$$

Where l_{1j}= 0 (lower limit) and l_{2j}= 1 (upper limit) and are normal and standard density functions.

In a two-limit Tobit model, each marginal effect includes both the influence of explanatory variables on the probability of the dependent variable to fall in the uncensored part of the distribution and on the expected value of the dependent variable conditional on it being larger than the lower bound. Thus, the total marginal effect takes into account that a change in explanatory variable had a simultaneous effect on the probability of being efficient in rice production and value of efficiency scores in rice production.

Next to McDonald and Moffitt (1980),Greene (2004) and Gould *et al*. (1989) cited in Bealu *et al*. (2013), from the likelihood function decomposition of marginal effects was proposed as follows two-limit Tobit model:

The unconditional expected value of the dependent variable

$$\frac{\partial E(Y)}{\partial X_j} = [\varphi(Z_U) - \varphi(Z_L)].\frac{\partial E(Y^*)}{\partial X_j} + \frac{\partial[\varphi(Z_U) - \varphi(Z_L)]}{\partial X_j} + \frac{\partial[1 - \varphi(Z_U)]}{\partial X_j} \ldots \ldots . \ldots \ldots 4.1$$

The expected value of the dependent variable conditional upon being between the limits

$$\frac{\partial E(Y^*)}{\partial X_j} = \beta_M.\left[1 + \frac{\{Z_L \emptyset(Z_L) - Z_U \emptyset(Z_U)\}}{\{\varphi(Z_U) - \varphi(Z_L)\}}\right] - \left[\frac{\{\emptyset(Z_L) - \emptyset(Z_U)\}2}{\{\varphi(Z_U) - \varphi(Z_L)\}2}\right] \ldots \ldots \ldots \ldots \ldots \ldots \ldots .4.2$$

The probability of being between the limits

$$\frac{\partial[\varphi(Z_U) - \varphi(Z_L)]}{\partial X_j} = \frac{\beta_m}{\sigma}[\emptyset(Z_L) - \emptyset(Z_U)] \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .4.3$$

Where,φ . = the cumulative normal distribution, ∅ . = the normal density function $Z_L = -\frac{X_j\beta}{\sigma}$= and $Z_U = \frac{(1-X_j\beta)}{1}$ are standardized variables that came from the likelihood function given the limits of y* and σ = standard deviation of the model.

3.5.3. Hypothesis test

The following null and alternative hypotheses for choice of the frontier production function and efficiency model was tested in this study. The null hypothesis, that Coob-Douglas production function is best fit the data and there are no technical inefficiency effects in the model is conducted by testing the null and alternative hypothesis Ho: $\gamma = 0$ and H1: $\gamma > 0$. The test was performed as a one sided test for the reason that γ cannot take negative values. As a result, the One-sided GLR test suggested by Coelli (1995) should be performed when maximum likelihood estimation is involved.

This test statistic requires the estimation of the model under both the null and alternative hypotheses defined as.

$$LR = \lambda = -2\{\text{Ln}[\text{L}(\text{Ho})] - \text{Ln}[\text{L}(\text{H1})] \quad \ldots\ldots 4.4$$

Where: L (Ho) = value of the likelihood function under null hypothesis

L (H1) = value of the likelihood function under alternative hypothesis.

In this case if Ho: $\gamma = 0$ is true the LR has asymptotic distributed which is a mixture of Chi- square distributions, namely $^1/_2\, \chi_0^2 + ^1/_2\, \chi_1^2$ (Coelli 1995). Then the critical value for the One-sided GLR test of Ho: $\gamma = 0$ versus H1: $\gamma > 0$ can simply calculate. The critical value for a test of size α is equal to the value, χ_1^2 (2 α), where this is the value exceeded by the χ_1^2 random variable with probability equal to 2α. Thus the one-sided generalized likelihood ratio test of size α is: "reject Ho: $\gamma = 0$ in favor of H1: $\gamma > 0$ if LR exceeds, χ_1^2 (2 α).

3.6. Definition of variables and working hypothesis of the Study

In this study, the following variables were selected based on the reviewed literatures, theoretical and/ or empirical justification and rice production characteristics.

3.6.1. Production variables

These variables include both the output (dependent) and inputs which are the independent factors of production, used in the production process of rice.

Dependent variable

Output: Is the total rice production obtained in Qt in2017/18 production year.

Independent variables

I. Land (LND): The total area of land in ha allocated for rice by the i^{th} farmer in this production year.

II. Labor (LAB): was a continuous variable that the total labor force used for plowing, planting, weeding and cultivation which was measured in terms of man-days.

III. Oxen power (OPR): The total number of pair of oxen days used by the i^{th} farmer from land preparation up to harvesting that is, oxen power used by the farmer in all oxen-driven rice production activity and measured in pair of oxen-days.

IV. Fertilizer (FRTI): Its continuous variable refer to the total amount of chemical fertilizer measured in kg (both Urea and DAP) applied by the i^{th} farmer on rice field in 2017/18 production year.

V. Seed (SE): The total quantity of rice seed used by the i^{th} farmer measured in kg and it is continuous variables.

VI. Chemicals (CHEM): Chemical (herbicides) was used as an input particularly in rice production by the i^{th} farmer due to weed as input variable, the physical quantity of chemicals in liter was applied for weed protection for rice during 2017/18 production season.

Input prices: The input prices that were used to estimate the cost function were collected using primary and secondary data during peak and slack periods. The unit price for land was estimated using the local average rental cost in the area, which was 3000Birr/ha. For labor the average wage rate for hired labor, 75 Birr/MD was used. For oxen power the average rental value of a pair of oxen per day (150 Birr) was taken. The price for fertilizer (DAP and Urea) was not possible to aggregate into one variable as the price variations are high. This is because the resulting difference in EE would not be only due to input variations but also price variations. So for Urea and DAP the current market values of 10.27 and 12.87 Birr/kg, respectively were used. As far as seed and herbicide concerned, the current market values of 7.5 Birr/kg and 160 Birr/L (kg) respectively were used.

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

Y_i = f(LAND, LABOR, OXEN,UREA, DAP, SEED, CHEMICAL; βi) +ε_i…………4.5

Where: Y_i = Output of the i^{th} farm (Qt)

F (.) = appropriate functional form (e.g. Cobb-Douglas)

β_i = vector of unknown parameters to be estimated

ε_i = composed error term ($\varepsilon_i = V_i - U_i$)

V_i = a disturbance term which accounts for factors outside the control of the farmer

U_i = non-negative random variable which captures the technical inefficiency.

3.6.2. Efficiency variables

1. Sex of the household head (SEXHH): This was a dummy variable measured as 1 if the HH is male and 0, otherwise. Wudineh and Endrias (2016) sex of household has positive and significant impact on TE. This report indicates, those female headed households were less efficient technically than male headed households in the production of barely in Chole District, Ethiopia. Therefore, it was hypothesized that the male farmers are more efficient economically than female farmers.

2. Age (AGHH): It was measured as age of the HH in years. The age of the farmer can be a proxy measure for the experience of the HH in farming. This means that older farmers are more experienced in farming activities and are better to assess the risks involved in farming than younger farmers (Mustefa *et al*.,2017).On the other hand Age contributed negatively to EE, in other words, younger farmers were relatively more efficient than older farmers. The reason might be younger farmers had more contacts with extension agent services, plot demonstration and agricultural meetings (Bealu *et al*., 2013).Therefore, in this study it was hypothesized that, there was indeterminate relationship between age and efficiency of rice production.

3. Non-farm income (NFIC): it was a dummy variable having value of 1 if household got non-farm income and 0, otherwise. The effect on the production of farmers being involved in non-farm activities might be two fold. First, if farmer spends more time on non-farm activities relative to farm activities, this may negatively affect agricultural activities Hassen (2016).

Second, income generated from non-farm activities might be used to acquire to purchased inputs and hence, positively complement farm activities Oladimeji and Abdulsalam (2013). Consequently, it was hypothesis that non-farm income has both positive and negative effect on economic efficiency of rice production.

4. Education (EDU): It was a continuous variable measured by the number of years that the rice farmer spent in school. According to Musa *et al*. (2015) educational level was significant and positively related to AE and EE. The positive sign indicates that an increase in human capital enhances the efficiency of farmers. It was agreed with Hassen (2016) found that through education the quality of labor is improved and this increased experience and better management of farm activities. Therefore, in this study education was hypothesized to affect TE, AE and EE positively.

5. Frequency of extension contact (FEXC): This was a continuous variable. Defined as the number of time extension agent visited the farmer during stated production season. According to (Musa *et al.*, 2015), EE study of maize production in central rift valley of Ethiopia, frequency of extension contact had significant positive relationship with TE. The frequent contact facilitates the flow of new ideas between the extension agent and the farmer, thereby giving a room for improvement in farm efficiency. Advisory service rendered to the farmers can help farmers to improve their average performance in the overall farming operation as the service widens the household's knowledge with regard to the use of productivity and input allocation. From this, extension contact was hypothesized to have positive impact on TE, AE and EE of rice production.

6. Household size (HHSIZ): It was the family size of the household measured in man-equivalent. Family labor constitutes the major labor supply to the farm. Sisay *et al*. (2015) found that family size in the production of maize in Southwestern Ethiopia, positively affects EE of smallholder farmers. However finding by (Tadesse *et al.*, 2016) oppose with this idea. That is family size has negative impact on TE. This might be due to the fact that households with large family size tend to spend more on consumption goods and thus expenditure on rice yield improvement, like agrochemical was minimal. Thus it is difficult to forecast a prior, whether it influences the TE, AE and EE of rice producing farmers in the study area positively or negatively. Due to this, it was hypothesized to have an intermediate relationship to TE, AE and EE.

7. Land Fragmentation (LFRG): The variable land fragmentation represents the number of parcels of land on which farmers allocated for their rice production. According to Mustefa *et al*. (2017**),** land fragmentation had negative and significant impact on TE and AE. Fragmented land leads to inefficiency by creating shortage of family labor, wastage of time and other resources that should been available at the same time. Moreover, as the number of plots operated by the farmer increases, it may be difficult to manage these plots. Hence, it was hypothesized to have negative effect on EE of rice production.

8. Credit utilization (CRUT): A dummy variable represents the use of any forms of credit associated with rice production by farmers. Dawit *et al.* (2013) found, that credit has positive and significant impact on TE. This indicates that the availability of credit for resource poor farmer is important to finance the agricultural activities. Therefore, it was hypothesized that farmers who have used credit are expected to be economically more efficient than others.

9. Cultivated land (CLTAND: This was a continuous variable, which represents the total crop area in ha managed by a farmer. It is important to evaluate whether relatively large farm size holder are more efficient or not than small ones. As the farm size of a farmer increases, the managing ability of him/her will decrease given the level of technology. According to Endrias *et al. (*2013) farm size, significantly affect the TE of smallholder maize producers in Wolita and Gemu Gofa. Therefore, it was hypothesized that farm size had negative effect on EE of rice producing farmer.

10. Proximity to the market (PRXIMKT): This variable was a proxy by the average distance between the most nearest market center and farmers home in hour. Proximity to market affected the efficiencies in different ways. It was assumed that proximity to markets increased the opportunities of farmers to sell their products and purchase input at nearest distance (Bealu *et al*., (2013). In contrast, some research argued that access to markets might increase the non-farm employment opportunities with higher returns than farming, leading farmers to reallocate labor from farm to non-farm activities (Wondimu and Hassen, 2014). But for this study it was hypothesized that farmers who are near to market center were technically, allocatively and economically more efficient than farmers far away from the nearest market center and vice versa.

11. Livestock holding (LIVS): This variable stands for the number of livestock owned by the household in tropical livestock unit (TLU). It is assumed to reflect the wealth of household and could help the farmer in diversifying the level of risk associated with rice farming. The money from this helps the farmer to secure his/her livelihood and enable them to purchase more inputs, which helps them to maintain rice production. It also serves as shock absorber to an unexpected hazard in crop failure and the main sources of animal labor in crop production (Getachew *et al*., 2012 and Solomon, 2012). For that reason, the effect of livestock on EE was hypothesized to be positive.

12. Distance (DSTA): It was the average time the farmer must travel from the residence to the plots. This is measured in hour. In many empirical studies, it was hypothesized that distance between plot and home decrease the level of efficiency of farmers. (Alemayhu, 2010) finding in line with this idea. It was hypothesized that distance between plot and home decrease the level of efficiency of farmers and vice versa.

13. Cooperative Membership (MCOOP): This variable was captured by binary variable having the value of 1 if the HH is participating in cooperatives other ways 0.This variable might have information and time effects on production efficiency. In fact if farmers are member to cooperative he or she spends time on this cooperative, especially if he/she was a leader of cooperative. This might hurt farm activities. On the other hand, the degree of social life increases as long as the farmer is member to cooperatives. This enables farmers to exchange farming experience, access to market information and easier even for extension staff to offer extension services. This could help the farmer in improving the level of productivity and EE (Bealu *et al.*, 2013).Thus membership to cooperative expected to have positive or negative impact on TE, AE and EE.

Table 3: Summary of variables included in the production function

Variables	Description	Measurement	Sign
	Dependent variable		
Rice out put	Total rice output	Qt	--
	independent variables		
Land	Total cultivated area for rice	Ha	+
Labor	Total labor (family and Hired) used	Man days	+
Oxen	Total number of Oxen owned	Pair of oxen days	+
Urea	Amount of Urea used	Kg	+
DAP	Amount of DAP used	Kg	+
Seed	Seed input applied for rice farm	Kg	+
Chemicals	Herbicides used for rice weed	L	+

Source: Own review (2018)

Table 4: Summary of efficiency variables

Dependent variables	Measurement	Type	Expected sign
TE,AE and EE	-----	Continuous	-----
	Independent variables		
Sex of HH	1=male 0=female	Dummy	+,if male
Age of HH	Years	Continuous	+/-
Non-farm income (NFIC)	Birr	Dummy	+/-
Education level (EDLHH)	Years	Continuous	+
Extension contact (FEXC)	Frequency	Continuous	+
Household size (HSize)	Man-equivalent	Continuous	+/-
Land fragmentation (LF)	Number	Continuous	+
Credit utilization (CUT)	1=user 0=non user	Dummy	+, if user
Total cultivated land (TCL)	Hectare	Continuous	-
Proximity to market(PMKT)	Hours	Continuous	+
Livestock ownership	TLU	Continuous	+
Plot distance to home (PDH)	Hour	Continuous	-
Member to cooperative(MCOOP)	1=members 0=non members	Dummy	+/-

Source: Own review

4. RESULTS AND DISCUSSION

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

4.1. Descriptive statistics results

Before starting on discussing results obtained from the econometric models, it is important to briefly describe the demographic, farm, socio-economic and institutional characteristics by categorizing in to continuous and dummy variables. This would help to draw a general image about the study area and sampled households.

4.1.1. Descriptive statistics result of some important continuous variables

Age of sample households: The average age of the sample households during the survey period, was about 40.54 years with standard deviation of 9.60 (Table 5). This implies that majority of the farmers are still in their active age and thus expected to be positively contribute to rice production.

Household size: The average household size of the sample households was 4.66 and 6.2 in man-equivalent and persons, respectively, with standard deviation of 2.4979 (table5). The result implies that the mean (6.2) household size in the study area was relatively higher than the national average agricultural household size, which is about 5.2 persons per household (Essa, 2011).

Educational status: Education is an instrument to enhance the quality of labor through improving the managerial skill and the tendency to adopt new technologies. In addition to this, it would help farmers to able to produce higher output using the existing recourses more efficiently through increasing their information acquisition and decision making abilities. The survey result indicated that on average education level of the sample HHs was about 1.11 years with the minimum of zero years (illiterate) and maximum of five years (Table 5).

Frequency of Extension Contact: extension service was focused on providing advisory services on major agronomic practices such as: - land preparation as well as preparation and application of chemicals and fertilizer, post-harvest handling, soil and water conservation practices. The woreda assigned development agents in each *Kebeles*. The major sources of agricultural information for farmers are extension agents. A regular contact with extension agents makes farmers to be aware of adoption of new technologies, which helps them to maximize the agricultural production and productivity. The extension agent visit farmers on different intervals, some farmers are being visited more frequently while others have got less chance at all to be visited by extension agents. The frequency of extension contact recorded ranges between 0 and 11with a mean of 5 times during 2017/18 rice production year (Table 5).

Proximity to market: Access to market infrastructure is one of the key constraints in successful participation of smallholder farmers in market oriented agricultural production. Moreover, the intensity of their integration is highly dependent on access to markets. Proximity to the market is one of those main policy target variables that must be taken in to account in actions targeting to improve marketing, resource use efficiency and productivity of smallholder framers. Accordingly, the survey result, on average sample farmers 'took 0.28 hrs from the residence to reach nearest market (table 5).

Table 5: Descriptive analysis results of continuous explanatory variables

Variables	Mean	Std. Deviation	Min	Max
Age of HH	40.54	9.60	22	60
Education level of HH	1.11	1.41	0	5
Household size	6.2	2.7	2	12
Household size (Man-equivalent)	4.66	2.498	1.8	9.9
Frequency of extension contact	5.00	2.65	0	11
Proximity from market(hrs)	0.28	0.38	0	2
Livestock ownership (TLU)	3.58	2.38	0	15.25

Source: own computation (2018).

Livestock ownership: Livestock have a considerable contribution for household income and food security. Among others, oxen were a major input in rice production process serving as a source of draft power. Even if farmers in the study area used oxen to undertake different agronomic practices, out of which ploughing and threshing were the major ones. The sample household farmers on average owned livestock of 3.58 TLU ranging from zero to 15.25 TLU (Table 5).

In Guraferda woreda land preparation is done using a pair of oxen, as the result indicate below table 6, 33.1% of the sample households cannot independently plough their farm using own oxen.

Thus as an alternative, they were go for oxen exchange arrangements or rent-in from others. There was variability in oxen ownership among farmers in the study area, ranging from zero to four. In general 54.7% of sample households in the study area had a pair of oxen. Moreover, out of the total sample households during the survey period, 8.8% had at least three oxen (Table 6).

Table 6: Oxen ownership of sample households

Number of oxen	Number of respondents	Percent
Zero ox	13	8.8
One ox	36	24.3
Two oxen	81	54.7
Three oxen	13	8.8
Four oxen	5	3.4

Source: own survey result (2018)

4.1.2. Descriptive statistics result for some selected dummy variables

Sex of smallholder farmers: With regards to sex of smallholder farmers, about (42) 28.38% of farmers were female and the remaining (106) 71.62% were male (Table 7). It is obvious that female smallholder farmers face greater challenges in the agricultural production compared with their counterparts. This is due to the fact that female are the one who were responsible for the many household domestic activities, they might not accomplish the farming activities on time and efficiently. Besides, female smallholder farmers have less practical experiences in farming operation and would probably use minimum inputs than male smallholder farmers.

Non-farm income: In Guraferda woreda, farmers are engaged in various non-farm activities in parallel with the main farming activities during the farming season. The non-farm income sources in the study area include; selling of local drinks, handcraft or weaving, house rent, trading and petty treading. Income from non-farm activities plays a greater role in the livelihood of rural societies especially for subsistence-oriented households. Table 7, indicates that out of total sample households 61 (41.22%) participated in non-farm occupation and the remaining 87 (58.78%) were not participated in the activity. They also mentioned that attractive income and mainly shortage of land as the reasons for their engagement in non-farm income activities.

Cooperatives membership: the survey result revealed that 77.70% of the HHs were member to cooperative around their locality while, the remaining 22.30% not member (table 7). This result indicates the essential contribution of cooperative membership for rice production.

Table 7: Descriptive analysis results of dummy explanatory variables

Variables		No. of HH	Percent
Sex	Male	106	71.62
	Female	42	28.38
Non- frame income	Yes	61	41.22
	No	87	58.78
Membership to Cooperatives	Yes	115	77.70
	No	33	22.30

Source: Own computation (2018)

4.1.3. Major crops production and area coverage

Guraferda is well known for its crop production potential. The major crops grown in the area includes rice, maize, sorghum and lentil. On average, sample households allocated 1.24 ha (44.60%) of the total cultivated land for rice production. Next to rice, sorghum and maize were crops that took the largest proportion of the household's total cultivated land covering 0.59 and 0.57 ha respectively. Moreover, lentil seed took certain shares of households total cultivated land covering, 0.38 ha (Table 8).

Table 8: Average production and area coverage of major crops by sample HH

		Area allocated in (ha)		Production (Qt)	
Types of crops	N	Mean	Percent	Mean	Percent
Rice	148	1.24	44.60	26.11	44.89
Maize	82	0.57	20.50	15.12	25.98
Sorghum	97	0.59	21.22	10.62	18.25
Lentil	9	0.38	13.67	6.33	10.88

Source: Own computation (2018)

The survey result also demonstrates the average production of major crops in Qt. Given the difference in productivity among crops, sample households on average got 26.11Qt of rice, which is 44.89% of total production. The total average production of maize was 15.12 Qt (25.98%) of the total major crops production. Sampled households on average got 10.62 and 6.33 Qt of sorghum and lentil, respectively (Table 8).

4.1.4. Summary statistics of variables used in production function models

The production function was estimated using seven input variables. The mean and standard deviation of input variables is summarized and described in Table 9. On average, sample households produced 26.11Qt of rice, which is dependent variable in the production function. The land allocated for rice production, by sample households during the survey period, ranged from 0.25 to 3.00 ha with an average of 1.24 ha.

Table 9: Summary statistics of variables used to estimate the production function

Variables	Unit	Mean	Std. Deviation	Mini	Max
Output	Quintal	26.11	14.77	5	80
Labor	Man-day	133.77	52.57	34.50	250
Land	Hectare	1.24	0.53	0.25	3.00
DAP	Kilogram	46.12	31.10	0	150
Urea	Kilogram	65.54	54.33	0	300
Seed	Kilogram	128.61	56.54	25	350
Chemical	Liter	2.42	1.37	0.33	7
Oxen power	Pair of oxen days	9.02	5.28	2	32

Source: Own computation (2018)

On average, the amount of seed that sample households used was 128.61 kg. Like other inputs, human labor and animal power inputs were also important, given a traditional farming system in this area. On average, sample households used 133.77 man equivalent labor and 9.02 pair of oxen days for rice production during 2017/18 production year. In the study area, sample households used inorganic fertilizer both Urea and DAP for rice production. Hence, on average households used 65.54 and 46.2 kg of Urea and DAP per hectare, respectively. On average, about 2.42 liters of chemicals (herbicides) were used for rice production during 2017/18 production year (Table 9).

Similar to the production function, the mean and standard deviation of each variable used in the cost function along with their contribution to the total cost of cultivation are summarized and presented in Table 10. The total cost of Birr 18542.70 was required to produce 26.11Qt of rice.

Table 10: Summary statistics of variables used to estimate the cost function

Variables	Unit	Mean	Percent	Std. Deviation
Output	Qt	26.11	-	14.77
Cost of output	Birr	18542.70	-	12204.36
Cost of land	Birr	4051.24	24.28	3173.58
Cost of labor	Birr	7867.16	47.15	4949.27
Cost of oxen power	Birr	2098.92	12.58	1753.50
Cost of DAP	Birr	551.32	3.30	458.80
Cost of urea	Birr	709.05	4.25	1044.13
Cost of seed	Birr	842.41	5.05	438.27
Cost of herbicide	Birr	564.66	3.38	413.95

Source: Own computation (2018)

Table 11: Summary of efficiency model variables

Variable	Mean	Std.Dev	Percentage of the mean with Dummy=1	Percentage of the mean with Dummy=0
Age of HH (years)	40.54	9.34	-	-
Education (year)	1.11	1.41	-	-
Household size	4.66	2.498	-	-
Frequency of	5	2.65	-	-
Land fragmentation	1.40	0.52	-	-
Proximity to market	0.28	0.38	-	-
Distance from plot	0.399	0.31	-	-
Livestock ownership	3.58	2.38	-	-
Total cultivated land	2.53	1.10	-	-
Non- farm income	-	-	41.22	58.78
Credit utilization	-	-	33.78	66.22
Sex of farm	-	-	71.62	28.38
Membership to	-	-	77.70	22.30

Source: Own survey result (2018

Among the various factors of production, the cost of labor and land accounted for the highest share 47.15% and 24.28%, respectively. Following cost of labor and land, cost of oxen power, seed and Urea takes 12.58%, 5.05% and 4.25%, respectively out of total cost of cultivation. Among other inputs, cost of chemicals (herbicides) and DAP took the smallest 3.38% and 3.30%, respectively shares out of the total cost of rice production.

4.2. Econometric results

Under this, section the econometric results, such as production and cost functions, efficiency scores and determinants of efficiency are presented and discussed.

4.2.1. Test of hypothesis

Prior to proceeding to the estimation of the parameters of the model from which individual level efficiencies are estimated, therefore it is crucial to examine various assumptions related to the model specification. Accordingly, two hypotheses were tested. The first test was to select the correct functional form for the given data set best fits the data and the other hypothesis that tested was that, all coefficients of the inefficiency effect model were simultaneously equal to zero (i.e. Ho: = $\delta_0 = \delta_1 = \delta_2 \ldots = \delta_{13} = 0$). In other words, it was to check whether the explanatory variables in the inefficiency effect model contribute significantly to inefficiency variations among rice growing farmers. The hypotheses for the parameters of the frontier model were conducted using the generalized likelihood (GLR) ratio statistics, λ form can be defined as:

$$LR = \lambda = -2\{\mathrm{Ln}[\mathrm{L(Ho)}] - \mathrm{Ln}[\mathrm{L(H1)}] \ldots \ldots \ldots \ldots \ldots 4.6$$

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

Table 12: GLR tests of hypothesis for the parameters of the SPF

Null hypothesis	LH_O	LH_1	Calculated X^2 (LR) value	Critical value (χ2, 0.95)	Decision
H0: = $\beta_{ij} = 0$	29.69	10.23	38.92	41.34	Accept
H0: = $\delta_1 = \delta_2 \ldots = \delta_{13} = 0$	10.23	67.20	113.94	22.36	Reject Ho

Source: model output (2018)

The first test was the null hypothesis that identifies an appropriate functional form between restrictive Cobb Douglas versus non-restrictive Translog production function. This specifies that square and cross terms are equivalent to zero. The Cobb-Douglas and the Translog functional forms are the most commonly used stochastic frontier functions in the analysis of EE in production.

The Translog frontier function turns into Cobb-Douglas when all the square and interaction terms in the Translog are zero. In order to choose between the two alternative functional forms that can better fit to the survey data collected, the null hypothesis that all the interaction and square terms are all equal to zero (H0 : $\beta ij = 0$), i.e. Cobb Douglas frontier functional specification, is tested against the alternative hypothesis that these coefficients are different from zero ($H_1 : \beta ij \neq 0$).The decision to select functional form depends on the calculated GLR, which can be computed from the log likelihood value obtained from estimation of Cobb-Douglas and Translog functional specifications using equation (4.6). Then, this computed value is compared with the upper 5% critical value of the X^2 at the degree of freedom equals to the difference between the numbers of explanatory variables used in the two functional forms (in this case df = 28). For the sample respondents, the estimated log likelihood values of the Cobb-Douglas and Translog production functions were 10.23 and 29.69, respectively. The computed value of likelihood ratio (LR = -2(29.69 – 10.23) = 38.92 is lower than the upper 5% critical value of the X^2 with its respective degree of freedom (Table 12). Thus, the null hypothesis that all coefficients of the square and interaction terms in Translog specification are equal to zero was not rejected. This implies that the Cobb-Douglas functional form adequately represents the data.

The second null hypothesis that the explanatory variables associated with inefficiency effects are all zero (H0: $\delta_1 = \delta_2 \ldots = \delta_{13} = 0$) was also tested. To test this hypothesis likewise, (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: H0) and the full frontier model (a model with explanatory variables that are supposed to determine inefficiency of each: H1). For the sample households, the calculated value λ(LR) = - 2(10.23 – 67.20) = 113.94 is greater than the critical value of 22.36 at 13 degree of freedom (Table 12) the value of LR implying that, the null hypothesis (H0) that explanatory variables are simultaneously equal to zero was rejected at 5% significance level. As a result, the null hypothesis is rejected in favor of the alternative hypothesis that the explanatory variables associated with inefficiency effects model are simultaneously different from zero. Hence, these variables simultaneously explain the differences in inefficiency among farmers in the study area.

4.2.2. Estimation of production and cost functions

Under this, section econometric results, such as production and cost functions, efficiency scores and determinants of efficiency are presented and discussed. The stochastic production frontier was applied using the maximum likelihood estimation procedure. The dependent variable of the estimated model was rice output (Qt) produced during 2017/18 production year and the input variables used in the analysis were area under rice (ha), labor (man-days), oxen (pair of oxen-days), Urea (kg), DAP (kg), seed (kg) and chemical(herbicide) (L).

Table 13: Estimation of the Cobb-Douglas frontier production function

		Maximum likelihood estimate	
Variables	Parameter	Coefficients	Std.Err.
Cons	β_0	5.522***	0.381
LN Labor	β_1	0.185***	0.056
LN Land	β_2	0.464***	0.066
LN DAP	β_3	0.052***	0.007
LN Urea	β_4	0.010	0.007
LN Seed	β_5	0.171***	0.066
LN Chemical (herbicide)	β_6	0.129***	0.039
LN Oxen power	β_7	0.201***	0.044
Sigma square (σ^2)		0.125***	0.023
Lambda		2.729	0.062
Log likelihood function		10.230	
Gamma (γ)		0.882	
Return to scale		1.041	

**** represents significance at 1%, Source*: Model output (2018)

The frontier model analysis result indicated that, all the input variables in the production function except Urea, that is land under rice, oxen power, labor, seed, herbicide and DAP had a positive and significant effect on the level of rice output. The coefficients of the production function are interpreted as elasticity. Hence, land has high elasticity of output (0.464) suggests that rice production was relatively sensitive to land. As a result, 1 % increase in number of land in ha was result in 0.464% increase in the rice production, keeping other factors constant. Alternatively, this indicates rice production was responsive to land, followed by oxen power, labor, seed, herbicide and Dap by 0.201, 0.185, 0.171, 0.129 and 0.052%, respectively.

Gamma (γ) takes values between zero and one ($0 \leq \gamma \leq 1$), and reflects validity of the random disturbances (V_i, U_i) proportion. If γ is closer to zero, it indicates that the gap between actual output and the maximum possible output mainly comes from other uncontrolled pure random factors, which makes the use of stochastic frontier model meaningless. In contrast, if γ is closer to one, it shows that the gap comes mainly from the effects of one or more exogenous variables. In this study the gamma (γ) calculated as $\gamma = \frac{\delta_U^2}{\delta_S^2} = \frac{\lambda^2}{1+\lambda^2}, \delta_S^2 = \delta_V^2 + \delta_U^2$ alternatively and the output of this model indicate that, ratio of the standard error of u (δ_u) to standard error v (δ_v), known as lambda (λ), was 2.729. Based on λ value, gamma (γ) which measures the effect of technical inefficiency in the variation of observed output can be derived ($\gamma = \lambda^2/ (1+\lambda^2)$. The estimated value of gamma was 0.882, which indicated that 88.2% of total variation in rice farm output was due to technical inefficiency. This indicates that using stochastic frontier production function model is more appropriate.

The presence or absence of technical inefficiency was also tested in the study using the important parameter of log likelihood in the half normal model $\lambda = \sigma u/\sigma v$. if $\lambda = 0$ there were no effects of technical inefficiency and all deviations from the frontier were due to noise as stated in Aigner *et al*. (1977) the estimated value of $\lambda = 2.729$ significantly different from zero. The null hypothesis that there is no inefficiency effect was rejected at 5% level of significance, suggesting the existence of inefficiency effects for farmers in Guraferda woreda.

According to the model result of SPF the diagnostic statistics of inefficiency component reveals that sigma squared (δ^2) was statistically significant at 1 percent, which indicates goodness of fit and the correctness of the distributional form assumed for the composite error term (Table 13).

Another important analysis obtained from the coefficient of the Cobb-Douglas SPF was returns to scale. It serves as a measure of total factor productivity (Gbigbi, 2011). The coefficients were calculated to be 1.041, indicating increasing returns to scale. This implies that there is potential for rice producer farmers to continue to expand their production because they are in the I^{st} stage of production, where resources use and production is believed to be inefficient. In other words, a percent increase in all inputs proportionally was increase the total production by1.041% (more than1%).

This result is consistent with Mustefa (2014) who estimated the returns to scale to be 1.039% in his study of EE of barely production in Chole District. But a study by Bealu *et al.* (2013) on maize production in Boricha Woreda in Sidama zone found returns to scale to be 0.9588, which falls in stage II of production surface.

Table 14: Estimation of the Cobb-Douglas frontier cost function

Variables	Parameters	Maximum likelihood estimate	
		Coefficient	Std. Err.
LNLand cost	β_1	0.001	0.052
LNLabor cost	β_2	0.346***	0.048
LNOxen cost	β_3	0.133***	0.020
LNDAP cost	β_4	0.016***	0.005
LNUrea cost	β_5	0.003	0.004
LNSeed cost	β_6	0.054	0.037
LNChemical cost	7_7	0.122***	0.025
LNoutput	β_8	0.357***	0.071
Cons	β_0	1.394***	0.139

The dual cost function which is specified in equation (2.9) and derived analytically from the stochastic cost function was given as follows:

$$lnc_i = 1.394 + 0.001\phi_1 lnC_{land} + 0.346\phi_2 lnC_{labor} + 0.019 lnC_{Inorganicfertilizer} + 0.054\phi_4 lnC_{seed} + 0.122\phi_5 lnC_{chemicals} + 0.133\phi_5 lnC_{oxenpower} + 0.357\delta \ln Y* \ldots\ldots\ldots 4.7$$

Where C is the minimum cost of production of the ith farmer, Y* refers to the index of Output adjusted for any statistical noise and scale effects and ω stands for input prices.

The result of MLE of the stochastic cost frontier model indicated that the cost input variable such as cost of labor, oxen, dap and herbicide had a positive and significant effect on the level of total production cost of output. The cost elasticity with respect to these input variables used in the production analysis were positive and implied that an increase in the cost of labor, oxen, DAP and cost of herbicide increases total rice production cost. The model result indicated that 1% increase in the cost of labor, oxen, dap and herbicide would increase total cost of production by 0.346%, 0.133%, 0.016% and 0.122%, respectively.

4.2.3. Efficiency scores of sample households

The results of the efficiency scores indicate that there were wide ranges of differences in TE, AE and EE among rice producer households. The mean of TE was found to be 78.50%. Which reveals that farmers on average could decrease inputs (land, DAP, Urea oxen, labor, herbicide and seed) by 21.5% to get the output they are currently getting, if they use inputs efficiently and the mean AE of rice producer household was 80.56%, this showed that, rice producer households can save 19.44% of their current cost of inputs if they use the right mix of inputs given their prices. The average EE of sample households was 63.18%.The model output presented (Table 15) indicates that sample households in the study area were relatively good in AE than TE and EE.

Table15: Summary of descriptive statistics of efficiency measures

Type of efficiency	Mean	Std. Deviation	Minimum	Maximum
TE	78.50	0.1235	35.61	96.04
AE	80.56	0.1223	41.87	99.20
EE	63.18	0.1379	29.17	91.28

Source: model output (2018)

In a further form of analysis, the mean allocative efficiency of 80.56% (Table 15) means that there is a need to improve the present level of allocative efficiency. Moreover, the estimates indicated that the farmers have an opportunity to increase their allocative efficiency. For example, farmer with average level of allocative efficiency would enjoy a cost saving of about 18.79% derived from (1 – 0.8056/0.9920)*100 to attain the level of the most efficient farmer. The most allocative inefficient farmer would have an efficiency gain of 57.79% derived from (1- 0.4187/0.9920)*100 to attain the level of the most technically efficient farmer.

The mean economic efficiency also showed that there was a significant level of inefficiency in the production process. That is the producer with an average economic efficiency level could reduce current average cost of production by 36.82%. To achieve the potential minimum cost level without reducing output levels. It can be inferred that if farmers in the study area were to achieve 100% economic efficiency, they would experience substantial production cost saving of 36.82%.

This implied that reduction in cost of production through eliminating resource use inefficiency could add about 36.82% of the minimum annual income.

Moreover, the result also means that the farmer with average level of economic efficiency would enjoy a cost saving of about 30.78% derived from (1-0.6318/0.9128)*100 to attain the level of the most efficient farmer. The most economically inefficient farmer would have an efficiency gain of 68.04% derived from (1- 0.2917/0.9128)*100 to attain the level of the most efficient farmer (Table 15).

The frequency distribution of TE result in figure 5 showed that the majority of the sample households have TE score of 81 to 90%. But there are also sample households whose TE levels were limited to the range of 31 to 80 were 45.9 % only. Sample households in this group have a room to enhance their rice production at least by 20%, on average. Out of the total sample households, 13.5% of the households have TE of greater than 90%. This implies that around 86.5% of the sample households can increase their production at least by 10%.

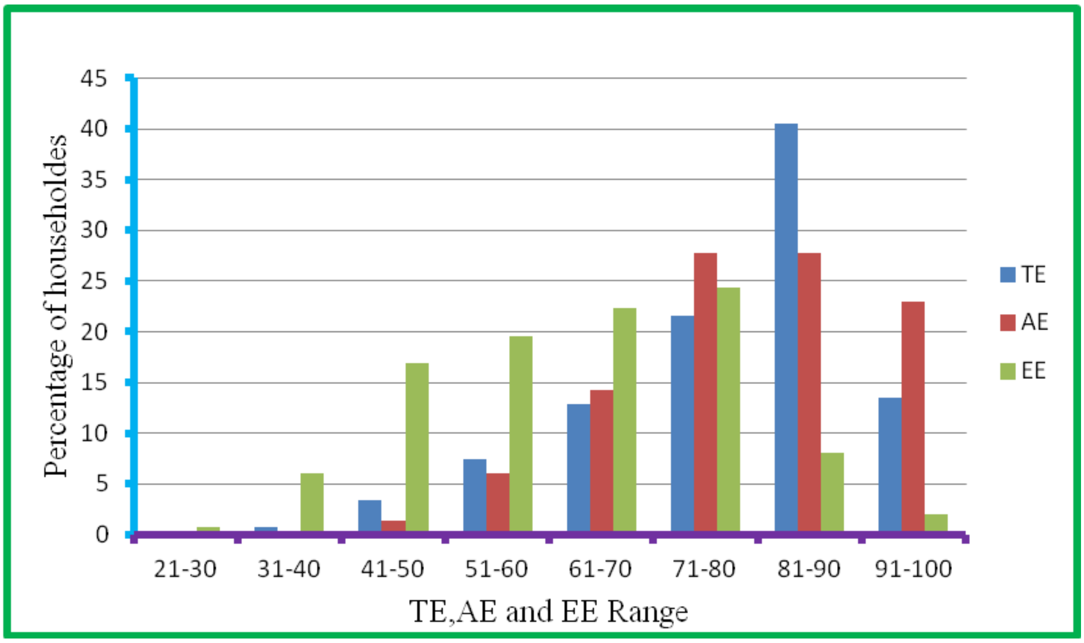

Figure 5: percentage distribution of TE, AE and EE scores

According to the result of AE scores (figure 5), the largest efficiency group of rice producers 27.7 and 27.7% operated between71-80 and 81-90%, respectively. Households in this group can save at least 20 and 10% of their current cost of inputs by behaving in a cost minimizing way, respectively. Only 23% of the total sample households had an AE score that ranged between 91and 100%.This shows that almost 77 % rice producing households can at least save 10% of their current input cost by reallocation of resources in cost minimizing way.

The distribution of EE scores implies that about 43.3% of the farmers were performing below average efficiency level (figure 5). The majority (24.3%) of rice producers in the study area were operated between 71% and 80%. Households in this group can save at least 20% of their current cost of inputs by behaving in a cost minimizing way. Only 2% of the total sample households had an EE score that ranged between 90 and 100%. This shows that almost all rice producing farmers (98%) can at least save 10% of their current input cost by reallocation of resources in cost minimizing way. The low level of EE was the total effect of both technical and allocative inefficiencies. This also indicates the existence of substantial economic inefficiency in production of rice during 2017/18 production year.

4.2.4. Determinants of TE, AE and EE in rice production

After determining the existence of efficiency differential among farmers by measuring the levels of their efficiencies, the second key objective of this study was finding out factors causing economic efficiency differentials among farmers. To observe this, the technical, allocative and economic efficiency estimates derived from the model were regressed on socio-economic, demographic, farm and institutional variables that explain the variations in efficiency across farm households using two-limit Tobit regression model. Table 16, illustrates these factors that affect efficiencies in rice production.

The estimates of the two limit-Tobit model showed that among the total, six variables (age, sex, household size, non-farm income, and frequency of extension contact and livestock ownership) were found to be significantly affecting the level of TE. Education, cooperative membership and proximity to market were significantly influence AE of rice production.

Lastly, the result of model also revealed that five variables (education, non-farm income, proximity to the market, membership to cooperative and frequency of extension contact) were important in influencing EE of households in the study area (Table 16).

Table 12: Two-limit Tobit model estimates result for TE, AE and EE measures

	Technical efficiency			**Allocative efficiency**			**Economic efficiency**		
Variables	Coef. (Std. Err.)	**ME** $\partial E(y^*))$	$\partial E(y)$ $\partial[\varphi(Z_U)-\varphi(Z_L)]$	Coef. (Std.Err)	**ME** $\partial E(y^*))$	$\partial E(y)$ $[\partial(\varphi(Z_U)-\varphi(Z_L)]$	Coef. (Std.Er	**ME** $\partial E(y)$ $[\partial(\varphi(Z_U)-\varphi(Z_L)]$	$\partial E(y^*)$
Age	0.002** (0.001)	0.0019	0.0019 (0.0009)	0.000 (0.001)	0.0001	0.0001 (0.0001)	0.001 (0.001)	0.0014 0.0001	0.0013
Sex	-0.058**** (0.018)	- 0.0580	-0.0571 (-0.0271)	0.031 (0.025)	0.0249	0 .0292 (0.0268)	-0.025 (0.025)	-0.0253 -0.0026	- 0.0243
EDHH	0.002 (0.007)	0.0021	0.0021 (0.001)	0.024** (0.010)	0.0195	0.0228 (0.0209)	0.022** (0.010)	0.0215 0.0022	0.0206
HH size	0.013*** (0.003)	0.0132	0.0130 (0.0062)	-0.004 (0.005)	- 0.0033	-0.0039 (-0.0035)	0.007 (0.005)	0.0067 0.0007	0.0065
NONFI	-0.027* (0.015)	- 0.0273	-0.027 (-0.0122)	-0.031 (0.021)	- 0.0251	-0.0293 (-0.0259)	-0.049** (0.021)	-0.0491 -0.0044	- 0.0471
FXCT	0.016*** (0.003)	0.0157	0.0155 (0.0073)	-0.005 (0.004)	- 0.0041	-0.0048 (-0.0044)	0.008** (0.004)	0.0083 0.0008	0.0080
LFG	-0.005 (0.016)	- 0.0048	-0.0048 (-0.0023)	0.003 (0.022)	0.0026	0.0031 (0.0028)	-0.003 (0.022)	-0.0029 -0.0003	- 0.0028
CRUT	0.004 (0.019)	0.0036	0.0036 (0.0017)	-0.031 (0.026)	- 0.0252	-0.0293 (-0.0249)	-0.024 (0.025)	-0.0235 -0.0021	- 0.0226
TCLD	0.011 (0.015)	0.0112	0.0052 (0.0110)	-0.008 (0.021)	- 0.0062	-0.0073 (-0.0067)	-0.003 (0.020)	-0.0029 -0.0003	- 0.0028
PROX MKT	0.030 (0.044)	0.0304	0.0299 (0.0142)	-0.206*** 0.062	- 0.1674	-0.1961 (-0.1799)	-0.163*** (0.061)	-0.1623 -0.0165	- 0.1558
PDH	-0.017 (0.030)	- 0.0171	-0.0168 (-0.0080)	0.013 0.041	0.0108	0.0127 (0.0117)	-0.006 (0.040)	-0.0055 -0.0006	- 0.0053
McooP	0.025 (0.024)	0.0247	0.0244 (0.0088)	0.090*** 0.033	0.0782	0.0873 (0.0436)	0.093*** (0.032)	0.0922 0.0030	0.0885
Livestock	0.007* (0.004)	0.0071	0.007 (0.0033)	0.002 0.005	0.0016	0.0019 (0.0017)	0.006 (0.005)	0.0059 0.0006	0.0057

***, ** and * refers to 1%, 5% and 10% significance level, respectively.

(Expected change) $\frac{\partial E(y^*)}{\partial x_j}$, (change in probabliy) $\frac{\partial[\varphi(Z_U)-\varphi(Z_L)]}{\partial x_j}$ &

(Total change) $\frac{\partial E(Y)}{\partial x_j}$ were used to compute the marginal effect.

Source: Model results.

According to the result of two -limit Tobit model presented in (table 16), from the explanatory variables that hypothesized to determined economic efficiency of smallholder rice producer, only the significant variables were discussed as follows:

Age of household head: The estimated coefficient of age for TE in table 16 had positive and significant at 5% significant level. This result indicates, as age HH increase their farming experience increase as a result their TE also rise. Moreover, the marginal effect of age for TE shows that, for sample period, an increase in age by one-year lead, increase the probability and change in expected value and with an overall increase in the probability and the level of TE by 0.09, 0.19 and 0.19%, respectively. The result was similar with Mustefa *et al*. (2017) and contradict among Wudineh and Endrias (2016); Fekadu and Bezabih (2009) and Bealu *et al*.(2013).

Sex of household head: It was found to have positive and significant effect on TE at 1%, which is corresponding to the hypothesis made. The result indicated that male HH was more efficient than female HH. The possible explanation is that male households were carried out most of the activities on the farm, especially on land preparation and had more frequent follow up and supervision of their farm and they might accomplished the farming activities on time and efficiently than female smallholder farmers. Besides male farmers are likely to be wealthier and capable of adopting new and expensive agricultural technologies might lead the positive relationship. In addition the two-limit tobit model ME indicate that a unite increase the dummy variables representing male and female HH order with 1 and 0, result increased the probability, expected value and overall increase the probability and level of TE by 2.71, 5.8 and 5.71%, respectively. This result is also similar with the finding of Wudineh and Endrias (2016) and it is in contrast with Mesay *et al*. (2013) finding on Source of technical inefficiency of smallholder wheat farmers in selected waterlogged areas of Ethiopia.

Education: Education had positive and significant effect on both AE and EE with expected sign at 5% significance level. Education enhances the acquisition and utilization of information on improved technology by the farmers. The results showed that farmers with more years of formal schooling were more efficient than their counterparts (Table, 16).The significant effect of education on AE and EE confirms the importance of education in increasing the efficiency of rice production. The result indicates that, AE and EE require better knowledge and managerial skill than TE. In other words, educated households have relatively better capacity for optimal allocation of inputs.

The computed ME result also indicate that, a one year increase in educational attainment level of the HH increases the probability of a farmer to fall under AE and EE category by 2.09 and 0.22% and expected value of AE and EE by about 1.95 and 2.06% with an overall increase in the probability and levels of AE and EE by 2.28 and 2.15%, respectively. The result is line with Musa *et al*. (2015) and Solomon (2012).

Household size: Family size was hypothesized to have either positive or negative effect on EE, due to its consumption or labor force contribution effect on production. However, number of family size in the household has a positive and significant impact on TE at1% level of significance. The result indicates that labor force contribution effect is leading than consumption effect for rice production. A possible reason for this result might be, due to the fact that, a larger household size guarantees availability of family labor for farm operations to be accomplished in time. At the time of peak seasons, there is a shortage of labor and hence household with large family size would deploy more labor to undertake the necessary farming activities like ploughing, weeding and harvesting on time than their counterparts and for this reason they are efficient in rice production. Moreover, the three computed ME result of household size showed that a one-person increase in the number of household size would increase the probability, expected value and overall the probability and level of TE of smallholder farmers by about 0.62, 1.32 and 1.3%, respectively. The result is similar with Sisay *et al*. (2015) and dissimilar to Tadesse *et al.* (2016).

Non-farm income: It has negative effect on TE and EE and statistically significant at 10 and 5% significant level, respectively (Table15). This negative and significant effect of non-farm income on TE and EE indicates that farmers engaged in non-farm income earning activities tend to exhibit lower level of TE and EE. This might be because farmers may allocate more of their time to non-farm income generating activities and thus may lag in agricultural activities. On the other hand, incomes from non-farm activities may be used as extra cash to buy agricultural inputs and can improve risk management capacity of farmers. However, the result shows that agricultural lag effect of non-farm activity has dominated its income effect. Furthermore, the two-limit Tobit model ME result indicates that, a one percent increase in participating in non-farm income generating actives would result in, decrease probability fall under TE and EE category by 1.22 and 0.44%, expected value by about 2.27 and 4.71% and with an overall decrease in the probability and the level of TE and EE by 2.7 and 4.91%, respectively. This result was consistence with the findings of Hassen (2016) and Asefa (2012).

Frequency of extension contact: The coefficient of frequency of extension contacts had significant and positive relationship with TE and EE at 1 and 5% significance level, respectively. This result indicates that, farmers who had more number of extension contact during the cropping period were technically and economically more efficient than those who had less number of extension contact during 2017/18 production period. Thus, the consultation of extension services increases rice production by increasing level of TE and EE. This implies that a frequent contact facilitates the flow of new ideas between the extension agent and the farmer thereby giving a room for improvement in rice efficiency. Moreover the ME result revealed that a unit increase the frequency of extension contact leads to increase the probability fall under TE and EE category by 0.73 and 0.08%, expected value by about 1.57 and 0.8% and with an overall increase in the probability and the level of TE and EE by 1.55 and 0.83%, respectively. This result is in line with the results of Musa *et al*. (2015), Sisay *et al*. (2015) and Tadesse *et al* .(2016) and opposing to Jema (2008).

Proximity to market: In line the hypothesis, the coefficient of AE and EE is found to be negative and statistically significant at 1% level of significance. This result showed that as distance increase from market farmer's allocative and economic efficiency reduced. This might due to present of areas that transport access not reached. As a result, farmers face difficulties to reach improved technology, transport inputs and farm product easily. Moreover, the marginal effect indicates that a unit increase distance to the market would decrease probability fall under AE and EE group by 17.99 and 1.65%, reduce the expected value by about by 16.74 and 15.58% and with an overall decrease in the probability and the level of AE and EE by 19.61%, and 16.23% respectively. This finding was agreed with Alemayhu (2010);(Bealu *et al*., 2013); Wondimu and Hassen (2014).

Membership to cooperatives: The coefficients of AE and EE of rice production were positively and significantly influenced by cooperative membership at 1% significant level. This result indicates that information effect of cooperatives dominated than time loses effect for rice production process.

That means farmers who were members of farmer cooperatives received viable information on production technologies than their counterparts. This could help the farmer to improving the level of productive efficiency.In addition, a unit increase in dummy variable representing member and non-member to cooperatives ordered with 1 to 0 would result in, increase the probability of the farmers to fall under AE and EE category by 4.36 and 0.3 % and increase the expected value of AE and EE by about 7.82 and 8.85% with an overall increase in the probability and the level of AE and EE by 8.73 and 9.22%, respectively. The result is agreed with Sisay *et al.* (2015), Bealu *et al*. (2013) and (Wudineh and Endrias, 2016).

Livestock (TLU): The last, but not least, explanatory variable that explains variation in TE was livestock ownership, measured in TLU. The coefficient of livestock ownership for TE was positive and significant at 10%. Positive and significant impact of livestock ownership on TE might be due to the importance of livestock in the crop production system as source of draft power, income and manure that may help to maintain soil fertility and result in maximization of output. It also helps the farmer in diversifying the level of risk associated with rice farming. Moreover the ME result (0.0033, 0.0007 and 0.0070) showed that, each unit increase in livestock ownership (TLU) would increase the probability, expected value and overall the probability and level of TE by about 0.33, 0.71 and 0.7%, respectively. This outcome is similar with Getachew *et al*. (2012), Wudineh and Endrias (2016) and Solomon (2014).But it contrasts with Hassen (2016).

5. CONCLUSSION AND RECOMMENDATIONS

5.1. Conclusion

The following important conclusion were emanating from economic efficiency analysis of rice production. In this study, there exists a considerable room to improve the level of TE, AE and EE of smallholder rice producers. The result of Cobb-Douglas production function indicated that land and oxen power were limiting constraints, with positive sign as expected. The positive coefficients of these variables indicate that, increased use of these inputs was increase the production level to better amount.

The average TE, AE and EE values of the sample households were 78.5, 80.56 and 63.18%, respectively. These implies that farmers can increase their rice production on average by 21.5% without increasing inputs if they were technically efficient, reduce current cost of inputs by 19.44% with cost minimization way and there was a room to improve EE by 36.82% when these farmers operate at full efficiency levels.

The key factors that affect the level of efficiencies were identified, to help different stakeholders to increase the current level of efficiency in rice production. Accordingly, age of household head, sex, household size, frequency of extension contact and livestock holding had positive and significant effect as expected on TE. This implies that farmers with older age, male sex, large number of household size(man-equivalent), more number of extension contact and more number of livestock were technically efficient than their counterparts. However, non-farm income had negative effect on TE. Therefore, we can conclude that, farm households who spent more of the time in non-farm income generating activities were technically less efficient than others.

Education level of household head and membership to cooperative had positive and significant effect on AE as expected. This implies households with better education level and cooperative members were more allocatively efficient than others. However, proximity to market had negative effect on AE. From this it can be conclude that farmers who far away from the nearest market center allocatively less efficient than these close to nearest market.

Lastly, education level of household head, frequency of extension contact and cooperative membership had positive and significant effect on EE as expected. From this we can conclude that household heads with better level of education, more number of extension contacts and cooperative members were economically more efficient than their counterparts. Nevertheless, distance from market and non-farm income had negative and significant effect on EE. It can also conclude that farmers who far away from nearest market and spent most of their time on non-farm income activities were economically less effacement than their opposed.

5.2. Recommendations

Based on the findings of this study, policy implications are made to enhance resource use efficiency and increase rice productivity in the study area. Finally, the following important recommendations are drown based on the result of this finding.

- Younger farmers were less technically efficient than older farmers were. Hence, continues training and follow up during farm operation for younger farmers is needed that might be provided by the woreda agricultural office, development agents and NGOs. However, this should not be without considering the older one.
- Female smallholder farmers were technically less efficient than male smallholder farmers were. Thus, promoting improved technologies that reduce the domestic burden of the female smallholder farmers would improve their technical efficiency level in rice production. Also capacity building on resource allocation in cost minimizing way, management of crop through training and experience sharing from male smallholder farmers to improve their technical efficiency level is essential.
- Education measured was an important determining factor that has a positive and significant impact on AE and EE in the study area. Thus, the woreda education office has needed to design appropriate policy to provide adequate and effective basic educational opportunities to the rural population, both formal and non-formal education like vocational schools for farmers in the study area. As a result, the households can use the right mix of input and input cost more efficiently under existing technology in rice production.
- Non-farm income has negative effect on technical and economic efficiency; the overlapping of both operations in time as well as their competitive nature for the labor input affects technical and economic efficiencies. Hence, it is relevant to suggest farmers' requests to properly allocate their family labor between farm and non-farm activities.

- The positive contribution of family size on technical efficiency of farm farmers' needs policy attention that would motivate and mobilize the rural population, particularly the youth, in agricultural activities by providing incentives.
- Cooperatives membership had positive and significantly effect on AE and EE. Thus, the woreda cooperative coordinator offices encourage, strength and organized non-member's farmer in to cooperative and cooperatives should have clear and production oriented missions. Furthermore, there must be active participation of farmers through giving leadership especially to those marginalized people including women that help member farmers to increase their resource allocation efficiency.
- Frequency of extension contact had significant and positive contribution to TE and EE. Therefore, the woreda agricultural office needs to focus to increase the number of visit farmers by extension agent and vice versa, by establishing additional development centers and by increasing the number of extension workers. Moreover the extension agents have given due attention for efficient input utilization and cost minimization in addition to their acknowledgeable effort to increase rice production.
- Proximity to market was found to have a negative influence on allocative and economic efficiencies of smallholder rice producers. Thus, development of market and road infrastructure could promote allocative and economic efficiencies and increase productivity. Therefore, policy makers need to focus on development of market and road infrastructure to facilitate market participation and integration of faraway distant resident smallholder rice producers.
- Given the mixed farming system in the study area, farmers with better number of livestock were relatively better in TE. As a result environmental friendly policy, initiatives that improve the livestock holding of farmers through improved livestock breeds, forage, nutrition and health services have to be considered from woreda livestock resource office.

Finally, there exists a considerable room to increase the level of economic efficiency of rice production and this study will be a benchmark for policy makers and researchers to improve the efficiencies and welfare of rice producer farmers.

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7. APPENDIX

Appendix Table 1. TE, AE and EE score of the sample household head (HH)

HHC	TE	AE	EE	HHC	TE	AE	EE
1	0.699238	0.606944	0.424398	28	0.693949	0.89611	0.621855
2	0.429109	0.679693	0.291662	29	0.852053	0.97138	0.827667
3	0.865617	0.723188	0.626004	30	0.608281	0.799973	0.486609
4	0.79953	0.843513	0.674414	31	0.857884	0.95811	0.821947
5	0.921583	0.703297	0.648146	32	0.881804	0.793071	0.699333
6	0.505897	0.971027	0.49124	33	0.903229	0.800572	0.7231
7	0.717249	0.849256	0.609128	34	0.670312	0.733721	0.491822
8	0.815484	0.854802	0.697077	35	0.899406	0.74893	0.673592
9	0.602386	0.671207	0.404326	36	0.623095	0.708247	0.441305
10	0.888119	0.827468	0.734891	37	0.505902	0.710972	0.359682
11	0.835316	0.964124	0.805349	38	0.953731	0.756052	0.721071
12	0.526332	0.887348	0.46704	39	0.839968	0.933318	0.783957
13	0.701464	0.640569	0.449336	40	0.582967	0.672817	0.39223
14	0.935982	0.973142	0.910843	41	0.79265	0.760403	0.602734
15	0.916675	0.894228	0.819717	42	0.485035	0.760824	0.369026
16	0.832796	0.836131	0.696326	42	0.855747	0.96324	0.82429
17	0.83375	0.971584	0.810058	44	0.827332	0.963325	0.79699
18	0.636005	0.708783	0.450789	45	0.586006	0.963681	0.564723
19	0.813183	0.604179	0.491308	46	0.356125	0.956529	0.340643
20	0.927097	0.984608	0.912827	47	0.868806	0.884125	0.768133
21	0.699666	0.939328	0.657216	48	0.598468	0.779904	0.466747
22	0.918068	0.846136	0.77681	59	0.715119	0.744927	0.532711
23	0.649729	0.869921	0.565213	50	0.555825	0.873802	0.485681
24	0.906157	0.887436	0.804156	51	0.64863	0.733939	0.476055
25	0.863292	0.906385	0.782474	52	0.770953	0.735787	0.567258
26	0.807836	0.729567	0.58937	53	0.7598	0.936088	0.711239
27	0.839233	0.882601	0.740708	54	0.788692	0.989627	0.780511

HHC	TE	AE	EE	HHC	TE	AE	EE
55	0.678048	0.71725	0.48633	82	0.926508	0.803357	0.744317
56	0.846875	0.725144	0.614106	83	0.743746	0.805338	0.598967
57	0.783686	0.973207	0.762689	84	0.797235	0.628605	0.501146
58	0.746138	0.701669	0.523542	85	0.843846	0.799234	0.674431
59	0.91567	0.760515	0.696381	86	0.876356	0.840544	0.736616
60	0.699424	0.775207	0.542198	87	0.780027	0.696504	0.543292
61	0.884759	0.77577	0.686369	88	0.719997	0.984009	0.708483
62	0.472902	0.819166	0.387385	89	0.785028	0.825402	0.647963
63	0.893532	0.832354	0.743735	90	0.791108	0.864105	0.683601
64	0.822693	0.987794	0.812651	91	0.848446	0.984249	0.835082
65	0.787479	0.813008	0.640227	92	0.902307	0.833704	0.752257
66	0.644065	0.567403	0.365445	93	0.948915	0.861478	0.81747
67	0.902237	0.756347	0.682404	94	0.834516	0.670121	0.559226
68	0.759723	0.607948	0.461873	95	0.917802	0.705355	0.647376
69	0.906677	0.813462	0.737547	96	0.873383	0.555983	0.485586
70	0.527015	0.873284	0.460234	97	0.927206	0.856867	0.794492
71	0.764374	0.637091	0.486976	98	0.817086	0.561075	0.458447
72	0.788305	0.982548	0.774547	99	0.915416	0.920544	0.842681
73	0.878131	0.930263	0.816893	100	0.753147	0.766451	0.57725
74	0.924263	0.658881	0.608979	101	0.902716	0.638487	0.576372
75	0.839673	0.60599	0.508833	102	0.872135	0.813682	0.70964
76	0.861082	0.599244	0.515998	103	0.888264	0.809771	0.719291
77	0.881821	0.898284	0.792125	104	0.815683	0.624804	0.509642
78	0.827132	0.822145	0.680023	105	0.78376	0.923026	0.723431
79	0.687844	0.872935	0.600443	106	0.953061	0.625289	0.595939
80	0.730902	0.858108	0.627193	107	0.897028	0.795552	0.713632
81	0.827137	0.954601	0.789586	108	0.731009	0.888384	0.649417

HHC	TE	AE	EE	HHC	TE	AE	EE
109	0.916968	0.598875	0.549149	129	0.834532	0.959311	0.800576
110	0.873152	0.793011	0.692419	130	0.779177	0.765797	0.596692
111	0.960383	0.889957	0.8547	131	0.646792	0.944885	0.611144
112	0.758023	0.749465	0.568112	132	0.905088	0.825942	0.74755
113	0.905594	0.418734	0.379203	133	0.865541	0.446949	0.386853
114	0.773722	0.884984	0.684732	134	0.588218	0.704244	0.414249
115	0.870308	0.676161	0.588468	135	0.632957	0.877134	0.555188
116	0.850575	0.837434	0.712301	136	0.824659	0.842812	0.695033
117	0.791729	0.618077	0.489349	137	0.641839	0.967668	0.621087
118	0.910491	0.725877	0.660904	138	0.739585	0.904146	0.668693
119	0.584585	0.723073	0.422698	139	0.884148	0.861294	0.761512
120	0.839477	0.935914	0.785678	140	0.860173	0.838365	0.721139
121	0.885054	0.992024	0.877995	141	0.806881	0.768299	0.619927
122	0.913926	0.791089	0.722997	142	0.705647	0.774096	0.546238
123	0.841092	0.747497	0.628713	143	0.666936	0.802167	0.534994
124	0.642223	0.967917	0.621618	144	0.735988	0.976673	0.718819
125	0.84204	0.773684	0.651472	145	0.817532	0.715721	0.585124
126	0.726262	0.802334	0.582705	146	0.868693	0.622311	0.540597
127	0.850181	0.940718	0.79978	147	0.536219	0.90328	0.484356
128	0.77178	0.750379	0.579127	148	0.835132	0.926257	0.773547

Source: own computation (2018) , Where, **HHC**=Household head code

Table 2.Frequency and percentage distribution of efficiencies scores

	TE		AE		EE	
Efficiency	Freq.	Percent	Freq.	Percent	Freq.	Percent
00-10	0	0	0	0	0	0
11-20	0	0	0	0	0	0
21-30	0	0	0	0	1	0.7
31-40	1	0.7	0	0	9	6.1
41-50	5	3.4	2	1.4	25	16.9

51-60	11	7.4	9	6.1	29	19.6
61-70	19	12.8	21	14.2	33	22.3
71-80	32	21.6	41	27.7	36	24.3
81-90	60	40.5	41	27.7	12	8.1
91-100	20	13.5	34	23.0	3	2.0

Appendix Table 3. Conversion factors used to estimate tropical livestock unit (TLU)

Animal category	TLU
Cow and ox	1
Calf	0.25
Weaned calf	0.34
Heifer	0.75
Sheep and goat (adult)	0.13
Sheep and goat (young)	0.06
Donkey (adult)	0.70
Donkey (young	0.34
Camel	1.25
Horse	1.1
Chicken	0.013

Source: Storck *et al*. (1991)

Appendix Table 4. Conversion factor for computation of man and adult equivalent

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

Source: Storck *et al.* (1991)

Appendix5. Questionnaire

Questionnaire Developed For '**EE of Smallholder Farmers in Rice Production: The Case of Guraferda Woreda, Southwestern Ethiopia**

Instruction: Tell the purpose of the study and introduce yourself before starting the interview. For all closed questions put (X) mark and circled where appropriate and use the space provided for open-ended questions.

Name of Enumerator ____________________________ Date of interview_______________

Identification Number __________________________ Kebele_____________________.

PART I. General Information about Sample Households

1. Name of household: ________________________.

1.2. Age of the household: _______ years.

1.3. Sex of the household: 1.[ ] Male 0.[ ] Female

1.4. Level of education: 0. [ ] Illiterate 1.if, literate (Specify level in years of formal education___________).

1.5. Marital status: 1.[ ] single 2.[ ] Married 3.[ ] Divorce 4.[ ] Widowed

1.6. Household's religion: 1.Orthodox, 2.Muslim, 3.Protestant, 4.Catholic.

1.7. Main occupation 1.[ ]Farmer 2. [ ] Non-farming: 3. [ ]. 4. [ ] off-farm

1.8. Years of experience in farming ____________________years.

1.9. For how many years did you cultivate rice? ___________years.

1.10. Number of family members and structure (including the head).

No	Name of family member	Sex1=male0=female	Age (years)	Kinship *	Engagement**
1					
2					
3					
4					
5					
6					

NB.**: 1=Head, 2= Wife, 3=Children, 4=Labor, 5= Relatives and 6=others*
***: (1=Full-time farmer, 2=Part-time farmer, 3=Full-time student, 4=Part-time student, 5=Casual laborer, 0=Disabled).*

A. Social Institutions

2. Do you have any information on formal or informal social institution in your locality?
1. [ ] Yes 0. [ ] No

2.1. If yes, what are the major social institutions? 1. [ ] Input supply coop. /union 2. [ ] Local administration 3. [ ] Edir 4. [ ] Equb 5. [ ] Saving and credit association

2.2. Are you a member of cooperatives? 1. [ ] Yes 0. [ ] No

2.3. If, yes, who participate in this cooperative? 1. [ ] Household head 2. [ ] Wife 3. [ ] children 4. [ ] Both HH and wife

2.4. If yes, for (Q3.3), what is your role? 1. [ ] Leadership 2. [ ] Committee 3. [ ] Member 4. Watch man

2.5. How many days on average do you spend per month in cooperatives? _______.

2.6. Who will take care of farming activities while executing your responsibility in cooperatives? 1. [ ] Family members 2. [ ] Hired workers 3. [ ] Relatives 4. [ ] The society

2.7. If not member of cooperatives, why? 1. [ ] Because it's not useful 2. [ ] Poor management 3. [ ] Ceased to exist 4. Has not production oriented mission

PART. II. Wealth, farm resources and off and non-farm income activities

A. Wealth Status, off and non-farm income generating activities

3. What is your relative wealth position? A. Very rice B. Rich C. Medium D. Poor E. poor

3.1. Is your house built with corrugated iron? 1. [ ] Yes 0. [ ] No

3.2. If yes, number of corrugated iron____________________

3.3. Did you have your own transportation facilities? 1. [ ] Yes 0. [ ] No

3.4 If yes, what is that? A. Motor bike B. Bike C. Horse D. Mule

3.5. Did you have any source of income other than farming? 1. [ ] Yes 0. [ ] No

3.6. If yes, please fill the table.

No.	**non-Farm activity**	No. of Family Members Engaged				Number of days worked in a month	Income per working day	Annual Income In ETB
		Male	Female	Both	children			
1	Selling local							
2	Petty trading							
3	Rent from asset							
4	Handicraft							
5	Clothes making							
6	Trading							
7	Carpenter							
8	Pension							
9	Ceramic							
Off farm activities								
1	Farm Wage							
12	Selling of wood							
13	Sell of crops							
14								

3.7. Why some members of your family are engaged in Off-farm and non-farm activities?

A. Shortage of land B. Excess family labor C. Attractive income D. External income source

3.8. Is the off-farm/non-farm activity usually done in holidays? 1. [ ] Yes 0. [ ] No

B. Livestock ownership and annual income

3.9. Do you have livestock 1.[ ] yes 0. [ ] No .if yes please fills the table below.

No.	Class of Livestock	number owned	Average price in ETB	TLU
1	Oxen			
2	Cow			
3	Heifer			
4	Calves			
5	Donkey			

6	Sheep young			
7	Sheep adult			
8	Goat young			
9	Goat adult			
10	Chicken			
11	Horse			
12	Mule			

C. Perennial crops and annual income

3.10. What are the major perennial crops you are growing? Please fill the table?

N$^{o.}$	perennial crops	Number of trees	Unit measurement	Amount produced	Quantity sold (if	Unit price	Total income
1							
2							
3							
4							
5							
6							

D.Annual crops produced and annual income

3.11. What are the major annual crops produced?

No.	Type of annual crop	Area (ha)	Quantity produced	Quantity sold (in qt.), if any	Unit price	Total income
1	Rice					
2	Maize					
3	Sorghum					
4	Teff					
5	Sesame					
6						
7						

E. **Farm implements**

3.12. Farm implements ownership in number and value

Farm implements	Number	unit price	Quantity	Total price
Ox-ploug				
Hoe				
Sickle				
Pick axe				
Knapsack sprayer				
Gejara				

III. Input and Output Information

4. Land use pattern: Total Area of land ____________ (ha) Homestead land_________(ha) Cultivated land_________________ (ha) Fallow land____________________ (ha) Grazing land___________________ (ha) other land_____________________ (ha)

4.1. Why you produce rice? A. High yield B. Required lower labor C. High grain price D. Stover (residue) yield E. Pest and disease tolerance F. No other alternative G. A&C

42. Have you involved in share cropping and land rent? 1. [ ] Yes 0. [ ] No

4.3. If yes, what is the size and rent of land? Please fill the table accordingly.

Description	Size(ha)	In kind	In cash	Proportion*
Owned				
Share in				
Share out				
Rent in				
Rent out				

A. Area allocated, fertilizer applied and seed used for rice production in 2017/18.

44. How many plots did you have?__________________plots.

4.5. On how many plots did you plant rice in 20117/18 production season? ________plot.

4.6. How far is your most distant rice farm far from your home? hour or walking minutes (on foot)? Please fill the table properly.

plots	From home		Distance b/n plots	Between plot	
	hour	Minute		Hour	minute
Plot1			P1 and p2		
Plot 2			P1 and P3		
Plot3			P2 and P3		

4.8. Do you use inputs in rice field? 1. Yes 0. No.

4.9. If yes, fill the following table properly using the given code below

Type of inputs	No. Plots	Plot size(ha)	Sources* A	Variety **B	Amount used in kg (lit)per ha	Cost per unit	Total cost
Rice seed	Plot1						
	Plot2						
	Plop3						
Dap							
	Plot1						
	Plot2						
	Plot3						
Urea							
	Plot1						
	Plot2						
	Plot3						
Organic fertilizer C***							
	Plot1						
	Plot2						
	Plot3						
Herbicide							
	Plot1						
	Plot2						
	Plot3						
Pesticide	Plot1						
	Plot2						
	Plot3						

*A*1. Farmers' cooperative 2.Research institution 3.NGOs 4. Private investors 5. Farmers 6. Own 7. Other, specify B**.1.local 2.improve 3.any other specify______C***.1.Green manure 2.Animal waste 3.Compost4.Others, specify___________*

4.10. If you are not used improved rice varieties why? 1. Too expensive 2. Not better than local varieties 3. It is dwarf 4. It is not easily accessible

4.11. What method did you use to apply fertilizer? 1. Split application 2. one time only.

4.12. If you do not use fertilizer, why? 1. Too expensive 2. Source is far from home 3. Not timely available 4. Shortages of fertilizers supply 5. Not good to apply on rice field

4.13. If you are not using organic fertilizer, why? 1. it's bulky to transport 2. I do not have animals to prepare it 3. Lack of awareness

4.14.If you use crop protection chemicals in rice filed, List name of chemicals___________________________, and sources ____________

4.15. If no, why? 1. Too expensive 2. Lack of knowledge 3. Not timely available 4. Not available at all 5. Not effective 6. Risky for animals

B. Amount of human and oxen power allocated for rice production.

4.16. What was your source of oxen for the 2017/8 production season? 1. Own 2. Rented 3. Shared 4. Borrowed

4.17. How many pairs of oxen did you apply from land preparation up to planting?______

4.18. How many times did you plow your rice farm? _______ Times.

4.19. Please fill the table below if you used oxen and human power in rice production.

Activities		No. of days	Animal labor No.	Family labor (number)				Hired labor No.		Debo No.		Exchange labor	
				Men	Women	Children				M	F	M	F
						M	F	M	F				
Land clearing	1st												
	2nd												
Land preparation	1st Plowing												
	2nd Plowing												
	3rd Plowing												
	4th Plowing												
Planting	Sowing &												
	Fertilizer												
Weed control	1st weeding												
	2nd weeding												
Harvesting													
Threshing													
Transportation													

4.20. IF you were overcome labor shortage in 2017/8 rice production season using these below stated alternatives please fill correctly.

Labor	Wage per day	age	Total days worked
If you were overcome labor shortage using hired labor			
Female			
Male			
If you were overcome labor shortage using Exchange labor			
Female			
Male			
If you were overcome labor shortage using Debo			
Female			
Male			

4.21. How many hours per day did you use?

1. Oxen_______hour 2. Family labor______hour 3. Hired labor____hour.

4.22. If any pair of oxen rented amount paid per day_______________birr

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

4.24. If there is any land to labor exchange, what is the proportion of land to labor?______

4.25. If there is any ox to land exchange, what is the proportion of ox to land?__________

C. Amount of rice produced in 2017/18 production year?

Type of land	Produced (Qt)	Plot ownership*	Previous field**
Plot1			
Plot2			
Plot3			

_***1.Own 2. Rented in 3. Shared in 4. Other, specify**1. Fallow 2. Legume 3.Virgin land 4. Other cereal crops 5. Maize 6.Horticultural crops 7. other*

IV. Information on rice production activities

5. How much of your land is covered by rice crop last year? ___________________

5.1. What is the earliest date of land preparation for rice? _______week of_______month.

5.2. What is the latest date of land preparation for rice crop? _______week of_____month.

5.3. At what time did you start land preparation this year? ________week of _____month.

5.4. How many times did you plough your rice land? __________________________.

5.5. What is the earliest date of sowing/ planting? _________week of ___________month.

5.6. What is the latest date of sowing/planting rice? _________week of _________month.

5.7. Is weeding rice crop a common practice? (1). Yes (2). No

5.8. If yes, when you start weeding rice? _____________Week of _________month

5.9. What method did you use for weeding? 1.Hand weeding 2. Hoeing 3 Used chemicals

5.10. When did you harvest your rice crop? _________Week of ________month

5.11. How much man-days you employed to harvest rice? _________________

5.12. From where did you get the additional labor requirement?

1. Family labor was enough 2. Debo 3. Employing daily laborers 4. Exchange labor

5.13. How many days after harvesting are required to thrash rice? ____________days

5.14. How many quintals of rice yield did you received this year? ____________Quintal

5.15. How much did you sell it _________Birr per kg _____________ per quintal Birr

5.16. What is your plan with regards to the area to be allocated for rice production in the coming production seasons? 1. Increase 2. Decrease 3. No change

V. Socio-economic and institutional factors

I. Extension Service

6. Did you have extension contact? 1. [ ] Yes 0. [ ] No

6.1. If yes, how many contact with (DA) per 2017/18 production season? _____________

6.2. How often does the extension worker visit you in this production period? _________

6.3. How often did you visit the extension workers in 2017/18 season? _______________

A.Training

6.4. Did you get any practical training over the last three years? 1. [ ] Yes 0. [ ] No

6.5. Did you ever receive any training outside the locality? 1. [ ] Yes 0. [ ] No

6.6. Did you pay any expense when you went to training? 1. [ ] yes 0. [ ] no

B. Credit service and saving

6.7. Did you use credit in 2017/18 production season? 1. [ ] Yes 0. [ ] No

6.8. If yes, how much many borrowed? __________ETB.

6.9. How many of those allocate for rice production? _______ETB.

Fill the following table (first start from formal credit, if any)

Types of credit*	Kind of credit**	Sources of credit***	Purpose*****	Amount	Interest (%)

1.Formal 2.Informal 3.Both **1 Short term 2. medium term 3. long term ***1.Commecial Bank 2.Omo micro finance Credit and Saving Institution 3. Traders 4.Relatives 5.Friends 6.Money lender 7. Other, specify__**1. Purchase inputs 2.school fee 3.Medical 4.Primary basic need 5.Buy livestock 6. Petty trade 7. Pay rent land*

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

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

6.13. Of the total amount you borrowed in production year 2017/18, how much proportions have you repaid? 1. Full 2. Half 3. More than half 4. Less than half

6.14. Which time frame is foreseen for the credit repayment? _________________months

6.15. Do you have a saving habit? 1. [ ] Yes 0. [ ] No

6.16. If, yes much do you save per year? _________________________Birr.

6.17. Where do you save? 1. Home 2. Commercial banks 3. Omo micro finance Credit and Saving Institution 4. Other, specify______

6.19. If the answer no, for (Q 10.15) why?__________________________

6.20. Is there any problems regards to credit? 1. [ ] Yes 0. [ ] No

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

VI. Marketing

7. Do you have enough market demand for your rice production? 1. [ ] Yes 0. [ ] No

7.1. If no, what are the major reasons? ____________________________________

7.2. Do you believe that the current market price for rice is fair (good)? 1. [ ] Yes 0. [ ] No

7.3. If no, what are the major reasons?_________________________________

7.4. How decided the price of your rice product in the market? 1. By the farmer himself 2. By the merchants 3. By the market 4. By the farmer and consumer

7.5. How far is the nearest market which you sell your rice product from your home?____ Minutes _______hours on foot___(km).

7.6. How do you transport your rice product to the market?

1. Using human labor 2. By car 3. Donkey 3.By cart

VIII. Information on production cost of rice (from land preparation to harvesting)

No	Cost item		Unit	Total quantity	Unit price	Total cost
		Pesticide				
		Herbicides				
2	Seed cost	Local				

		Improved				
3	Fertilizer	Urea				
		Dap				
4	Oxen Days					
5	Human Labor					
6	Rental Value of Land					

8. What are the major constraints of agricultural production?

1. Weed infestation 2. Crop disease 3. Crop pest 4. Seed shortage 5. Shortage of draft animal 6. Shortage of labor 7. Climate change

Thank you very much for your cooperation!!!!