ECONOMIC EFFICIENCY OF SMALLHOLDER FARMERS IN WHEAT PRODUCTION: THE CASE OF ABUNA GINDEBERET DISTRICT, OROMIA NATIONAL REGIONAL STATE, ETHIOPIA

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Economic Efficiency of Smallholder Farmers in Wheat Production: The Case of Abuna Gindeberet District, Oromia National Regional State, Ethiopia

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DEDICATION

I dedicate this thesis manuscript to my brother Mamo Aggama.

STATEMENT OF THE AUTHOR

I solemnly declare that this thesis is my original work and that all sources of materials used in this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc. degree at Jimma University College of Agriculture and Veterinary Medicine and is deposited in the University Library to be made available to borrowers under the rule of the Library. I seriously declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

The author was born in Bake Kalate kebele, Abuna Gindebarat district, West Shewa Zone of Oromia National Regional State, Ethiopia in September 1988. He attended his elementary education at Gitire Primary School; secondary and preparatory education at Kachisi Secondary and Preparatory School. After completion of his high school education, he joined Jimma University in September 2010 and graduated with BSc. degree in Agricultural Economics in June 2012. After his graduation, he joined Rift Valley University and worked as instructor for three years. In September 2015, he joined Mizan-Tepi University and worked as graduate assistant for one year. He joined Jimma University to pursue his MSc. degree in Agricultural Economics in September 2016.

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ACRONMYS ANDABBREVIATIONS

AE	Allocative Efficiency
AGDANRDO	Abuna Gindebarat District Agriculture and Natural Resource Development Office
COLS	Corrected Ordinary Least Squares
CSA	Central Statistical Agency
DEA	Data Envelopment Analysis
EE	Economic Efficiency
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
Ha	Hectare
Kg	Kilogram
LR	Likelihood Ratio
ME	Man Equivalent
MLE	Maximum Likelihood Estimation
NPS	Nitrogen, Phosphorous and Sulphur
OLS	Ordinal Least Square
Qt	Quintal
SFA	Stochastic Frontier Analysis
SPF	Stochastic Production Frontier
TE	Technical Efficiency
TLU	Tropical Livestock Unit
UNDP	United Nations Development Programme
WFP	World Food Programme

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ABSTRACT

In Ethiopia, increasing population pressure and low levels of agricultural productivity have aggravated the food insecurity situation by widening the gap between demand for and supply of food. Increasing productivity and efficiency in crop production could be taken an important step towards attaining food security. This study was aimed at estimating the levels of technical, allocative and economic efficiencies of smallholder wheat producers; and to identify factors affecting efficiency of smallholder farmers in wheat production in Abuna Gindeberet district, Oromia National Regional State, Ethiopia. A two stages sampling technique was used to select 152 sample farmers to collect primary data pertaining of 2016/17 production year. Both primary and secondary data sources were used for this study. Cobb-Douglas production function was fitted using stochastic production frontier approach to estimate technical, allocative and economic efficiencies levels, whereas two limit Tobit model was employed to identify factors affecting efficiency levels of the sampled farmers. The stochastic production frontier model indicated that input variables such as mineral fertilizers, land and seed were the significant inputs to increase the quantity of wheat output. The estimated mean values of technical, allocative and economic efficiencies were 78, 80 and 63% respectively, which indicate the presence of inefficiency in wheat production in the study area. A two-limit Tobit model result indicated that technical efficiency positively and significantly affected by sex of the household head, education, extension contact, off/non-farm activity and soil fertility but negatively affected by land fragmentation. Similarly, age, education, extension contacts and off/non-farm activity positively and significantly affected allocative efficiency. In addition, economic efficiency positively and significantly affected by sex, age, education, extension contact, off/non-farm activity and soil fertility. The result indicated as there is a room to increase the efficiency of wheat producers in the study area. The policy measures derived from the results include: expansion of education, strengthening the existing extension services, establish and/or strengthening the existing off/non-farm activities and strengthening soil conservation practices in the study area.

Key words: Cobb-Douglas, Economic efficiency, Ethiopia, Smallholder, Stochastic Frontier

1. INTRODUCTION

1.1. Background of the Study

Agriculture is a center driver of Ethiopian economy. Economic growth of the country is highly linked to the success of the agricultural sector. It accounts for about 36.3% of the Gross Domestic Product (GDP), provides employment opportunities to more than 73% of total population that is directly or indirectly engaged in agriculture, generates about 70% of the foreign exchange earnings of the country and 70% raw materials for the industries in the country (UNDP, 2018).Even though it is contributing a lot to the Ethiopian economy, the agricultural sector is explained by low productivity, caused by a combination of natural calamities, demographic factors, socio-economic factors; lack of knowledge on the efficient utilization of available; and limited resources (especially land and capital); poor and backward technologies and limited use of modern agricultural technologies (WFP, 2012). Moreover, the sector is dominated by smallholder farmers that are characterized by subsistence production with low input use and low productivity, and dependency on traditional farming and rainfall. The smallholder farmers, who are providing the major share of the agricultural output in the country, commonly employ less modern production technologies and limited external inputs (World Bank, 2007). Therefore, being agriculture dependent country with a food deficit gap, increasing crop production and productivity is not a matter of choice rather a must to attain food self-sufficiency.

Agricultural productivity can be increased through diffusion of improved technologies and/or by improving the productive ability of farmers. In other words, through introduction of modern technologies and/or by improving the efficiency of inputs such as labor and management at the existing level of technology, it is possible to boost agricultural output. However, these two are not mutually 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 that the need for the amalgamation of modern technologies with improved level of efficiency (Kinde, 2005). In countries like Ethiopia (having capital constraint), it is worthwhile to benefit from increasing productivity through improving resource use efficiency.

In sub-Saharan Africa, Ethiopia is the second largest producer of wheat, following South Africa. Wheat is one of the major staple and strategic food security crop in Ethiopia. It is the second most consumed cereal crop in Ethiopia next to maize. It is a staple food in the diets of several Ethiopian, providing about 15% of the caloric intake (FAO, 2015), placing it second after maize and slightly ahead of teff, sorghum, and enset, which contribute 10-12% each (Minot *et al.,* 2015).It has multipurpose uses in making various human foods, such as bread, biscuits, cakes, sandwich, etc. Besides, wheat straw is commonly used as a roof thatching material and as a feed for animals (Omer, 2015).

Wheat is cultivated in the highlands of Ethiopia, mainly in Oromia, Amhara, Southern Nations Nationalities and Peoples' Region (SNNPR) and Tigray regions. It is predominantly grown by smallholder farmers under rain-fed conditions.CSA (2017) report shows that, wheat is cultivated on over 1.69 million hectares of land, with an annual production of 4.5 million tons with a yield of 26.75 qt/ha, contributing about 15.63%of the total cereal production. In terms of area of production, wheat stands fourth by covering 13.49% of the total cereal crops areas preceded by *teff* (24.00%), maize (16.98%)and sorghum (14.97%). From total cereal production, wheat ranks fourth after maize, teff and sorghum in the country. Production of wheat has significantly increased over the past 10years. It has increased from 2.4 million tons in 2006/7 (CSA, 2007) to 4.2 million tons in 2015/16 (CSA, 2016) and to 4.5 million tons in 2016/17 (CSA, 2017).

In Oromia region, the total area covered by wheat was 898,455.57 hectare produced by 2.21 million smallholders; the total production was 26.64 million quintals; and average productivity was 29.65qt/ha(CSA,2017). According to Abuna Gindebarat district agriculture and natural resource development office reports of (2016/17), about 22,020 hectares of land was covered by cereal crops. Of these, 6,240 hectares of land was covered with wheat with total production of 174,721 quintals. Despite its increase in area and production, its productivity is low (28qt/ha) which is below the average of productivity in the region (29.65qt/ha). There was also variation of productivity among wheat producers in the district due to difference in inputs application rates and management practices like timely sowing. Therefore, this study is intended to estimate levels of efficiency and to identify factors affecting efficiency levels of smallholder wheat producers in the study area.

1.2. Statement of the Problem

The production of wheat in the country is very insufficient to meet the increasing demand for food for the ever-increasing population, forcing the country to import 30 to 50% of the annual wheat grain required (Jemal *et al.,* 2016). This is may be due to that ninety-eight percent of this crop is produced by resource-poor farmers. So, to meet the domestic needs of the country, increasing production and productivity of the wheat crop is needed and it may be achieved through improved crop management, particularly use of high yielding and disease resistant varieties coupled with improving the existing level of farmers efficiency.

Efficient production is the basis for achieving overall food security and poverty reduction objectives particularly in major food crops producing potential areas of the country (Tolesa *et al.,*2014). However, farmers are discouraged to produce more because of inefficient agricultural systems and differences in efficiency of production (Kifle *et al.*, 2017). When there is inefficiency; attempts to introduce new technology may not result in the expected impact since the existing knowledge is not efficiently utilized.

The presence of inefficiency not only limits the gains from the existing resources, it also hinders the benefits that could arise from the use of improved inputs. Hence, improvement in the level of efficiency will increase productivity by enabling farmers to produce the maximum possible output from a given level of inputs with the existing level of technology (Geta *et al.,* 2013; Mesay *et al.,* 2013; Sisay *et al.,* 2015).

Most of the empirical studies in Ethiopia show that there was a variation in the level of efficiency of smallholder farmers in wheat production (Fikadu and Bezabih, 2008; Mesay *et al.,*2013; Solomon, 2012; Awol, 2014; Tolesa *et al.,* 2014; Kaleb and Negatu, 2016; Hassen, 2016; Getahun and Geta, 2016). According to the results of these studies the main sources of variation was; farm size, livestock holding, land fragmentation, education, participation in off/non-farm activities, access to credit, family size, extension contacts and poor infrastructures, among the others. However, those factors are not equally important and similar in all places at all times. A critical factor in one place at a certain time may not necessarily be a significant factor in other places even in the same place after some time.

Many researchers, in different sectors, have done many performance evaluation studies in Ethiopia. However, the majority of farm efficiency studies are limited to technical efficiency (Fekadu and Bezabih, 2008; Mesay *et al.,* 2013; Hassen, 2016; Kaleb and Negatu, 2016;Assefa, 2016; Getahun and Geta, 2016). But, focusing only on technical efficiency (TE) understates the benefits that could be derived by producers from improvements in overall performance. Unlike technical efficiency, studies conducted on economic efficiency (EE) of wheat are limited (Solomon,2012; Awol, 2014). Moreover, there is no study done on economic efficiency of smallholder wheat producers in the study area. Therefore, this study was attempted to fill the existing knowledge gap.

1.3. Research Questions

The study has attempted to answer the following key research questions.

1. What are the levels of technical, allocative and economic efficiencies of smallholder wheat producers in the study area?
2. What are the factors that affect technical, allocative and economic efficiencies of smallholder wheat producers in the study area?

1.4. Objectives of the Study

1.4.1. General objective

The general objective of this study was to assess economic efficiency of smallholder wheat producers in Abuna Gindebarat District of West Shewa zone.

1.4.2. Specific objectives

The specific objectives of the study were:

1. To measure the levels of technical, allocative and economic efficiencies of smallholder wheat producers in the study area; and
2. To identify factors that affect technical, allocative and economic efficiencies of smallholder wheat producers in the study area.

1.5. Significance of the Study

Efficiency measurement is one of the most indispensible researchable areas in production economics. In most developing countries (like Ethiopia), where resources are scarce, farmers are not well educated, labor is abundant, extension trainings are inadequate, and agricultural capital is limited, studies on resource use efficiency will benefit the producers in the study area to optimize their production by not wasting their scarce resources through solving resource allocation problem at a given technology. This is because the ability of farmers to adopt modern technologies and achieve sustainable production depends on their level of efficiency. This will again play a vital role at large in fastening economic growth of the country in terms of rising rural income, achieving food security, increasing employment, and accelerating poverty reduction without injecting new investment on modern technologies.

An empirical investigation of farm specific efficiency helps to determine: the level to which farmers are using the existing technologies efficiently; how much it is possible to raise output with the existing technology; and eventually whether it is possible to raise productivity by improving efficiency with the given technology or to develop new technologies to raise agricultural productivity. The proper utilization of the existing technologies will make all the development efforts successful. Hence, improving farmers' efficiency could provide an alternative source of growth. Moreover, this study with other previous studies can be used as input for further studies to be made in universities and research institutions and help students doing research on efficiency as a reference.

1.6. Scope and Limitation of the Study

This study focused on assessing economic efficiency of smallholder farmers in wheat production by using data from one district and identifying factors that affect efficiency of smallholder farmers. It was conducted using a cross-sectional data which only reflects circumstances in a given year and may be affected by the specific climate of the year as agriculture in the country is dependent on weather condition. In addition, the result of cross-sectional data does not show inter-temporal differences in efficiency levels of households. Moreover, farmers in the study area do not keep records; they might face recalling problems of the past events and most likely they may give wrong information during the survey time.

1.7. Organization of the Thesis

This thesis paper is organized into five chapters. Chapter one discusses background of the study, problem statement, research questions, objectives of the study, significance of the study and scope and limitation of the study. The second chapter presents review of literature on the concepts of efficiency in general and the various methodological issues concerning efficiency measurements and its determinants. It starts by illustrating the theoretical concepts of efficiency and further review the efficiency measurement approach and models that are commonly used in efficiency measurements. Based on the review, empirical findings and conceptual frameworks are established. The methodology used in the study were discussed and presented in the third chapter. It starts with description of the study area followed by the sampling design, type and sources of data, method of data collection and analysis. Finally, this section discussed the hypothesized variables that are expected to affect efficiency of smallholder farmers in the study area.

Chapter four is dedicated to results and discussions. This results and discussion chapter is presented by two sections. In the first section, descriptive analysis of socio-economic, demographic, institutional and farm characteristics of the sampled households are presented. Results of descriptive statistics of inputs used for wheat production like land, labor, seed, oxen power and mineral fertilizers and determinants of efficiency variables that are used in the model are also summarized in this section. In the second section, the econometric model results are presented. It starts by hypothesis test pertaining to stochastic production function. Given the test results and consequently model specified in the study, parameter estimates of the stochastic frontier model and results of two-limit Tobit models are presented and discussed.

In the last chapter, chapter five a brief summarization of main results of the study, conclusions drawn and recommendations given based on significant variables are presented.

2. REVIEW OF LITERATURE

In this chapter, definitions of efficiency, efficiency measurement approaches, models of efficiency measurement, empirical studies on efficiency and conceptual framework are discussed briefly.

2.1. Definitions and Types of Efficiency

The theoretical framework for different types of efficiency definitions and types of firms' performance analysis was first introduced by Farrell (1957). Farrell had extended the former original works of Debreu (1951) and Koopmans (1951), who laid the foundation by introducing the concept of efficiency and the way firms' performance could be measured at the firm level in considering the input-output relationship. Farrell (1957) introduces two components of firm efficiency: The technical efficiency (TE) and the allocative efficiency (AE). According to Farrel, technical efficiency can be defined as the performance of the given firm to obtain maximum output from a given combination of input used with the given level of technology. The given firm is technically efficient, when the combination of inputs/ resources give rise to the maximum possible outcome and has no room for further improvement of the output of the firm. Moreover, it can be expressed as the physical relation between inputs/resources (basically labor and capital) and the final outcome/output. In a condition where the firm produced the same amount of output or larger than the previous production level while decreasing the use of at least one of the input in the production process, roughly indicates the existence of inefficiency in the production process.

The other type of efficiency is an allocative efficiency (AE), which refers to the capacity of the firm to use a set of inputs in optimal proportion with the given price and level of technology or it could be alternatively interpreted as the ability of a firm to produce a given level of output using cost minimizing input ratios. Allocative efficiency is widely seen as the benefit of the society in welfare economics (Palmer and Torgerson 1999).

Economic efficiency combines both technical and allocative efficiencies. An economically efficient input-output combination would be on both the frontier function and the expansion path.

Alternatively, economic efficiency (EE) refers to the proper choice of inputs and outputs 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).

Productivity improvement can be achieved due to improved efficiency, technological improvements or changes in the scale of production (Coelli, 1995). Efficiency, which is a central issue in production economics, is helping as a guide for allocation of resources (Farrell, 1957). In developing countries like Ethiopia, enhancing the efficiency of producers is the best option for productivity improvement.

2.2. Efficiency Measurement Approaches

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

2.2.1. Input-oriented efficiency measures

Originally input-oriented efficiency measurement concept is introduced by Farrell (1957).Input-oriented measure of efficiency means the minimum amount of input required to produce a given amount of output. Input-oriented measure of efficiency keeps the level of output constant. The fundamental aim to analyze input-oriented efficiency is to address the question that "by how much the quantity of factors of production need to be proportionally reduced to achieve the same level of output as before?"The input-oriented measure of technical and allocative efficiency is explained by taking firms that use two factors of production $X_1$and X_2 to produce a single output Q by considering the assumption of constant return to scale (Farrell, 1957).The assumption of constant return to scale allows the technology to be represented using the unit of isoquant. Farrell also discussed the extension of his method so as to accommodate more than two inputs, multiple outputs and non-constant return to scale.

In order to show the input-oriented efficiency and allocative efficiency concepts, Farrell (1957) had used a convex Iso-quant curve as shown in the figure 1 below. Fully technically efficient firm could be represented by the set of production points along the curve SS' in the figure 1. In a condition where the firm uses a factor of production represented by point P to produce a unit of output Q, the distance QP, represents the technical inefficiency level of that firm which is exactly equal to the amount by which all inputs could be proportionally reduced without reduction in output. In input-oriented efficiency measures, the technical efficiency of the firm is measured by the ratio: $\mathrm{TE} = \mathrm{OQ}/\mathrm{OP}$, which is equal to $1 - (\mathrm{QP}/\mathrm{OP})$, where QP/OP is the technical inefficiency portion of the firm. For technically efficient firm, the ratio of QP/OP is zero and the ratio of OQ/OP is equals to one. The value of technical efficiency of the firm is always found between 0 and 1, if the TE score is one, it indicates that the firm is technically efficient, which is represented by point Q in the Figure 1 as it lies on the isoquant curve and a value of zero implies that the firm is fully technically inefficient.

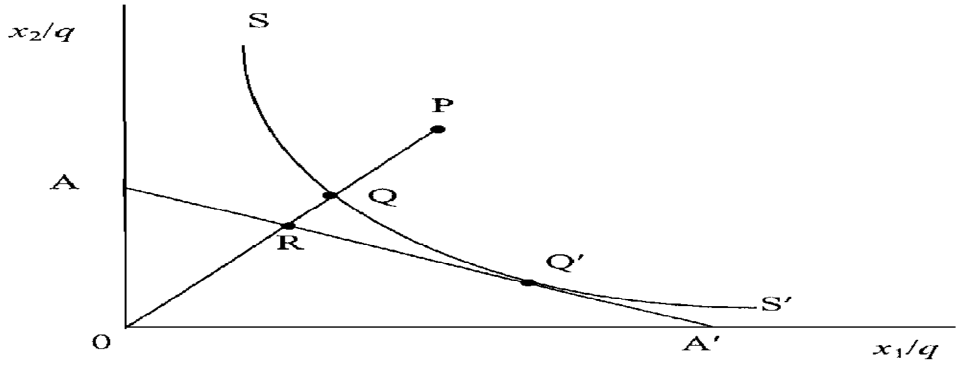
Moreover, the allocative efficiency measures the optimal proportion of a set of inputs to give the possible maximum output. Having this concept in mind, technically efficient firms which are on the Iso-quant curve may not necessarily allocatively efficient. Because investigating the allocative efficiency point requires price data of input and output beside the quantity of output in order to make the Iso-cost line AA'. The firm is said to be both technically and allocatively efficient at the point where the Isocost line AA' is tangent to the Iso-quant curve (SS') , which is point Q'. Point Q' is the point of the least cost combination of inputs from which the firm could derive the maximum output more than any point in the output space. In Input-oriented efficiency analysis, the ratio RQ/OQ represents the proportional reduction of cost (Coelli *et.al.,* 2005). As the firm removes the allocative inefficiencies and shrinks the ratio to zero, the level of input combination of the firm move from point Q to point Q'that is the point where the firm became allocatively efficient. The illustration of TE and AE of firm uses input P can be expressed as:

$$TE = \frac{OQ}{OP} \tag{2.1}$$

$$AE = \frac{OR}{OQ} \tag{2.2}$$

The Economic Efficiency of a given firm is the product ofTE and AE. This can be mathematically represented as:

$$EE = TE * AE = \frac{OQ}{OP} x \frac{OR}{OQ} = \frac{OR}{OP} \quad (2.3)$$



Source: Adopted from Coelli *et al.* (2005)

Figure 1: Input oriented measures of technical, allocative and economic efficiency

2.2.2. Output-oriented efficiency measures

Based on Coelli *et al.* (2005) and Farrel *et al.* (1994), input-oriented measure of efficiency has focused on how one could proportionally reduce the quantity of inputs mix without affecting the previous level of output. But one may need to address an inverse question that "by how much the output could be proportionally improved without changing the quantity of inputs that previously used?". Output-oriented efficiency measure is an exact inverse application of input-oriented efficiency analysis. In output-oriented measure of efficiency, the level of input is constant.

Output-oriented measures can be illustrated by considering the case where production involves two outputs (q1 and q2) and a single input (x). If the input quantity is held fixed at a particular level, the technology can be represented by a production possibility curve in two dimensions.

The segment AB represents the amount by which the output could be increased without adding an extra input. Hence, in the case of output-oriented efficiency measure, the technical efficiency is the ratio of OA/OB. If the price data is available, DD' line is an iso-revenue line and the firm at point B' is identified as allocatively efficient (AE) firm. The individual firm operated at point B seen as technically efficient firm.

In figure 2, the distance AB represents technical inefficiency. That is the amount by which outputs could be increased without requiring extra input. The distance function for output-oriented approach derives the TE andAE as follows:

$$TE = \frac{OA}{OB} \tag{2.4}$$

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

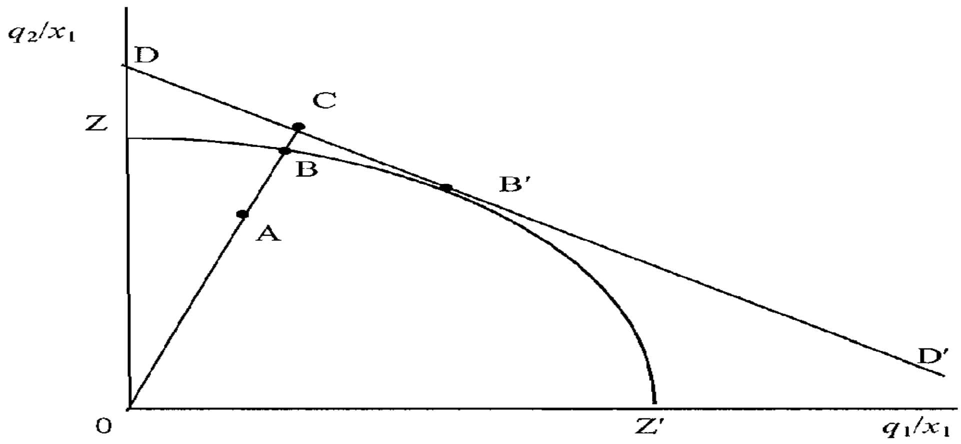
$$AE = \frac{OB}{OC} \tag{2.5}$$

which has a revenue increasing interpretation (similar to the cost reducing interpretation of allocative inefficiency in the input-oriented case).

Economic efficiency is again defined as the product of the two (technical and allocative) efficiencies:

$$EE = \frac{OA}{OB} X \frac{OB}{OC} = \frac{OA}{OC} \tag{2.6}$$

The point of tangency between the isorevenue line DD' and the production possibility curve ZZ' (point B') represents the economically efficient method of production, which is 100% technically and allocatively efficient. Again, all these three measures are bounded between zero and one.



Source: Adopted from Coelli *et al.*(2005)

Figure 2:Output oriented measures of technical, allocative and economic efficiency

2.3. Models of Efficiency Measurement

Efficiency measurements are basically carried out using frontier methodologies, which shift the average response functions to the maximum output or to the efficient firm. These methodologies are mostly categorized under two frontier models; namely parametric and non-parametric. The parametric models are basically estimated based on econometric methods and the non-parametric model, often referred to as Data Envelopment Analysis (DEA), involves the use of linear programming method(Coelli *et al.*, 1998). Efficiency measures assume that production function of the fully efficient firm is known. But this is different in practice, and the efficient isoquant must be estimated from the sample data. Farrell (1957) suggests the use of either (1) a non-parametric or (2) a parametric function such as Cobb-Douglas or translog production function.

The selection of specific frontier model depends upon many considerations such as the type of data, cross-sectional or panel data, the underlying behavioral assumptions of firms, the relevance to consider and extent of noise in the data and the objective of the study (Battese and Broca, 1996).

2.3.1. Non-parametric frontier model

The non-parametric approach of efficiency estimation is first introduced by Charnes, Cooper and Rhodes (1978). Data Envelopment Analysis (DEA) is one of the non- parametric approaches of measuring efficiency in agricultural production. It uses deterministic frontier models based on linear programming techniques to estimate technical efficiencies for each production unit non-parametrically (Banker *et al.,* 1984). The DEA fundamental assumption is that the whole deviation of firms from the production frontier is considered as firm specific inefficiency, which means this approach do not have a room to accommodate the random error (Coelli *et al.,* 2005). Data Envelopment Analysis (DEA) was proposed by considering input-oriented measure of efficiency operated under Constant Returns to Scale (Charnes *et al.*, 1978).

The primary advantages of DEA is; it can hold multiple inputs and multiple outputs, no requirement of a functional form for the specification of the input-output relation and a priori assumption with regard to the distribution of inefficiency parameter is not needed as in the case of parametric frontier models (Coelli *et al.,*1998).

However, DEA approach is not far from some limitations. The main criticism of DEA is that, it assumes all deviations from frontier is due to inefficiency (do not capture noise), while the best practice production frontier is estimated based on the information extracted from extreme observations, DEA scores are sensitive to errors in the data (Coelli, 1995).

The other drawback of DEA is that it is not possible to test the hypotheses regarding the existence of inefficiency and the structure of the production technology that were possible in stochastic production frontier analysis.

Generally many researchers, among others Endalkachew (2012), Hassen *et al.*(2012), Mesay *et al.* (2013), Awol (2014), Tolesa *et al.* (2014), Musa *et al.* (2015),Ermiyas *et al.*(2015), Sisay *et al.* (2015),Getahun and Geta (2016),Mustefa *et al.* (2017), Kifle *et al.*(2017), Nigusu (2018),and others agree and used that stochastic frontiers are likely to be more appropriate than DEA in agricultural applications of efficiency analysis. Therefore, the next section reviews various issues pertaining to parametric frontiers that are classified as deterministic and stochastic frontier methodologies.

2.3.2. Parametric frontier model

The other method of efficiency measurement is the one that uses econometric techniques to estimate the parameters of pre-specified functional forms. The parametric approaches try to estimate the efficiency scores by estimating an efficient frontier. Thus, the main difference between parametric and non-parametric approach is that while the parametric model estimates the efficient frontier by estimating the parameters of frontier, and then measures the distance of observed input-output data to the estimated frontier, the non-parametric approaches try to calculate the efficiency scores directly without estimating any frontier.

Parametric frontier model can further be classified into deterministic and stochastic frontier methods. The deterministic model assumes that any deviation from the frontier is due to inefficiency, while the stochastic approach allows for statistical noise (due to factors outside the control of the farmer like weather and diseases as well as measurement error).

2.3.2.1. Deterministic frontier model

Deterministic frontier function was first estimated by Aigner and Chu in (1968) by assuming a function giving maximum possible output as a function of certain inputs. Accordingly, the estimation of deterministic frontier production function using a Cobb-Douglas production function for a sample of N households was defined as follow:

$$\ln(Y_i) = F(X_i, \beta_i) - \mu_i \quad i = 1, 2 \ldots N \tag{2.7}$$

Where:

i −Denotes the number of sample households in the study area;

$\ln(\mathrm{Yi})$ − Denotes the natural log of (scalar) output of the i^{th}household;

X_i −Denotes a vector of input quantities used by the i^{th}household;

β_i −Denotes a vector of unknown parameters to be estimated;

$F(.)$ −Denotes an appropriate production function (Cobb-Douglas) and

μ_i −Denotes non-negative random variables which are assumed to account for inefficiency.

The main drawbacks of the deterministic frontier model is that it assumes the entire error term of the model as inefficiency of the firm, it does not account for possible influence of measurement error and other noise upon the shape and positioning of the estimated frontier (Coelli *et al.,* 1998). Hence, all observed deviations from the estimated frontier are thus, assumed to be the result of inefficiency. Therefore, the shortfall of the deterministic frontier model is that the model is unable to separate the composite error term into statistical noise and inefficiency term, which can be possible to set apart the random error term and the inefficiency term in stochastic frontier production function (SFPF)model. This is the major justification that magnifies the need of the SFPF, and makes the method most popular in recent efficiency analysis literatures.

In general, most empirical studies on efficiency analysis in agriculture used stochastic frontier model due to the very nature of agricultural output, which is affected by natural hazard, climatic condition and measurement errors that could attribute to the presence of noise in the data. In addition, Coelli *et al.*(1998) recommended that SFPF is more appropriate than DEA and deterministic model in agricultural applications, especially in developing countries, where the data are greatly influenced by measurement errors, and the effect of weather, disease, etc plays a significant role. Hence, most recent studies on efficiency in agriculture have used stochastic frontier model to account for random noise.

However, theoretical as well as empirical findings revealed that the smaller the random noise present on the data in question, the closer will be inefficiency estimates between these two deterministic and stochastic frontier models.

2.3.2.2. Stochastic frontier model

The stochastic frontier Approach (SFA) was developed independently by Aigner *et al.*(1977) and Meeunsen and Van den Broeck (1977). This stochastic frontier approach is developed to overcome the problem associated with random error in the deterministic approach. Frontier production functions are important for the prediction of efficiencies of individual firms in an industry and their applications have involved both cross-sectional and panel data.

The merits of this approach over Data Envelopment Analysis (DEA) (non-parametric) is that it accounts for a composite error term in the specification and estimation of the frontier production function. For a number of reasons, the stochastic frontier analysis (econometric) approach has generally been preferred in the empirical application of stochastic production function model in the developing countries agriculture like Ethiopia. This might be due to first the assumption that all deviations from the frontier arise from inefficiency as assumed in DEA is difficult to accept, given the inherent variability of smallholder agricultural production due to external factors like pests and weather conditions. Second, SFA is employed when the single output is produced by multiple factors of production, but DEA is appropriate for multiple inputs that are producing multiple outputs. Furthermore, smallholder farmers in Ethiopia in general and in the study area in particular are characterized by low level of education and keeping of records is thus non-existent.

The other advantage of stochastic frontier approach model is that it allows for estimation of standard errors and tests of hypotheses using maximum likelihood methods which the deterministic model fails to fulfill because of the violation of the Maximum Likelihood regularity conditions (Coelli, 1995).However, a serious shortcoming with SFA is that there is no priori justification for the selection of any particular functional form for the inefficiency component.

Assuming that producers are producing a single output using multiple inputs, stochastic frontier approach provides the relative frontier against which production performance is evaluated (Kumbhakar and Lovell, 2000). Accordingly, the stochastic production frontier was specified by adding a symmetric error term (v_i) to the non negative error term(μ_i) of the equation (2.7) as:

$$\ln(Y_i) = F(X_i, \beta_i) + v_i - \mu_i \; i = 1,2,3 \dots N \qquad (2.8)$$

In this equation $v_i's$ are assumed to be independent and identically distributed random errors following a normal distribution with zero mean and variance(σv^2). The random error v_i accounts for measurement error and other external factors such as climatic changes in production process which is out of the control of the producer; whereas the μ_i account for inefficiency of the firms.

Estimation of individual efficiency follows specification of stochastic production frontier. Accordingly, technical efficiency of i^{th}producer is estimated as the ratio of his/her actual output relative to the frontier output as in equation (2.9) below:

$$TE_i = \frac{Y_i}{exp(X_i\beta + v_i)} = exp(-\mu_i) = \frac{Y_i}{Y^*} \quad (2.9)$$

Where:

Y_i −Represent the actual output obtained in the presence of the technical inefficiency effects;

Y^* −Represent frontier output under condition of random shocks.

Its value lies between zero and one implying fully technically inefficient and efficient respectively.

Following Battese and Coelli (1995) the stochastic cost frontier function in equation (2.10) based on the specified production frontier in equation (2.9) was specified as:

$$\ln(C_i) = \beta_o + \sum_{j=1}^{K} \beta_j \, lnP_{ji} + v_i + u_i \qquad i = 1,2,3 \ldots N \quad (2.10)$$

Where:

lnC_i −Denotes the (logarithm of the) cost of production of the i^{th} firm;

P_{ji} −Denotes a vector of inputs price and output of i^{th} firm;

β_j −Denotes a vector of unknown parameter to be estimated;

v_i −Denotes random variables assumed to be independent and identically distributed random errors with zero mean and variance(σv^2).

u_i −Denotes non-negative random variables which are assumed to account for cost inefficiency and assumed to be independent and identically distributed random errors with zero mean and variance(σu^2).

Firm-specific allocative and economic efficiencies are computed from a dual cost function that is algebraically derived from the estimated parameters of the self-dual stochastic frontier production function (Kopp and Diewert, 1982). Accordingly, firm-specific economic efficiencies are computed as ratios of the weighted sums of economically efficient input quantities to the weighted sums of observed input quantities, the weights being the respective input price. Let, the observed and economically efficient costs of production of the i^{th}firm are equal to $(P_i{}'X_i)$and $(P_i{}'X_i{}^e)$, respectively. Thus, economic efficiency indices for the i^{th} firm were computed as:

$$EE_i = \frac{P_i{}'X_i{}^e}{W_i{}'X_i} \tag{2.11}$$

Following Farrell (1957) allocative efficiency (AE) indices for the i^{th} firm were computed as:

$$AE_i = \frac{P_i{}'X_i{}^e}{P_i{}'X_i{}^t} \tag{2.12}$$

Where:

$W_i{}'X_i{}^e$ −Denotes economically efficient costs of production;

$W_i{}'X_i{}^t$ −Denotes technically efficient input vectors;

The stochastic frontier production function parameters can be estimated using Maximum Likelihood (ML) or Corrected Ordinary Least Squares (COLS) method. Since, Corrected Ordinary Least Squares method is simple in analysis, it is advised to use. However, Maximum Likelihood method is asymptotically efficient than COLS. In addition, there are computer software to manipulate the complication in analyzing numerical solutions of maximum likelihood. Given this rational ML method is chosen than COLS whenever possible (Coelli, 1998).

2.4. Selection of the Functional Form

Parametric frontier methodology requires selection of specific functional form. Coelli *et al.* (1998) discussed three common functional forms namely Cobb-Douglas, Translog and generalized Leontief production functions. In the empirical estimation of frontier models the Cobb-Douglas functional form has been commonly used. Its simplicity is the most appealing feature. This simplicity is, however, associated with a number of restrictive features like constant elasticity, constant return to scale for all firms and elasticity of substitution are equal to one. The translog functional form imposes no restrictions up on returns to scale or substitution possibilities and the generalized Leontief form removes the return to scale restriction. But many studies indicate the Cobb-Douglas functional form is an appropriate specification over the translog functional form due to the following reason: Simplicity, the possibility of decomposing efficiency estimates into technical and allocative efficiencies (since the function is self-dual) and problem of multicollinearity associated with translog (Battese *et al.,* 1996).

Due to collinearity and loss of degrees of freedom caused by the multiple interaction terms included in the translog function form, a Cobb-Douglas production is preferable. It is also convenient in interpreting elasticity of production. In addition, variable returns to scale are likely to be rare in subsistence farming, making the homothetic assumption appropriate (Catherine and Jeffrey, 2013). As indicated by Bravo-Ureta and Evenson (1994) this functional form has also been widely used in farm efficiency analyses for both developing and developed countries.

Even though Cobb-Douglas model assumes unitary elasticity of substitution, constant production elasticity and constant factor demand; if the interest is to analyze the efficiency measurement and not analyzing the general structure of production function, it has adequate representation of the technology and insignificant impact on measurement of efficiency (Coelli *et al.,* 2005). When farmers operate in small farms, the technology is unlikely to be substantially affected by variable returns to scale (Coelli, 1995). The disadvantage of the Cobb-Douglas functional form is that it imposes strong assumptions on the nature of the farm technology (it assumes constant elasticity over the input-output curve and unitary elasticity of factor substitution). A study done by Kopp and Smith (1980) suggests that functional specification has only a small impact on measured efficiency. Ahmad and Bravo-Ureta (1996) also indicated that efficiency measures do not appear to be affected by the choice of the functional form.

The selection of specific production functions primarily depends on the objectives of the research. For instance, Sisay *et al.* (2015) employed Cobb-Douglas stochastic frontier model in the analysis of economic efficiency of smallholder maize producer farmers in southwestern Ethiopia and Hassen *et al.* (2012) on mixed crop-livestock production system in Ethiopia. In their studies, Cobb-Douglas production function is selected due to its advantage of computing self-dual cost function, which is a basis for estimating allocative and economic efficiencies. Others such as Endrias *et al.* (2010) used Translog stochastic frontier model on maize producing farmers and Shumet(2011) on selected crop among smallholder farmers in northern Ethiopia.

The other characteristic of stochastic frontier model associated with inefficiency effects is the type of distributional form for u_i. The specification of appropriate distributional form is the main criticism of the stochastic frontier model for it has generally no priori justification for its selection. There are many distribution forms for inefficiency effects like half-normal, truncated-normal and exponential distribution. Half normal distribution for Cobb-Douglas forms, truncated normal for Trans-logarithmic forms and exponential distribution for generalized Leontief models (Mbaga *et al.,* 2003). But, half-normal distributional form is the most common and almost universally assumed in empirical studies of efficiency analysis (Aigner *et al.,* 1977)

After functional form is selected and distributional form is assumed, the next issue in SPF analysis is the specification of inefficiency effects model. It is specification of those factors that may contribute for the difference in efficiency among firms. In order to analyze the determinants of efficiencies of crop production, two analytical approaches are suggested by different literatures. The one stage and two stage approaches. In one stage approach, efficiency effects are expressed as an explicit function of a vector of various independent variables. This approach is best suited to estimate only determinants of technical efficiency as in Battese and Coelli (1995). However, the method has been criticized due to its inability of estimating the determinants of allocative and economic efficiencies (Bravo-Ureta and Rieger, 1991). Various studies such as Kumbhakar *et al.*(1991); Battese and Coelli (1995); Getahun and Geta (2016) employed this approach to identify the determinants of technical efficiency of crop production.

The second approach is two-stage estimation procedure in which first efficiency or inefficiency index derived from either parametric and/or non-parametric approaches is taken as a dependent variable and is then regressed against a number of other explanatory variables that are hypothesized to cause efficiency variations using Tobit model. This approach has been criticized on grounds that the firm's knowledge of its level of technical efficiency affects its input choices;

hence efficiency may be dependent on the input variables. Second, if the variables used in the first-stage are highly correlated, it leads biased results due to multicollinearity. Despite of these disadvantages, Coelli *et al.* (1998), recommend the two-stage method in most cases, because it can accommodate more than one variable, can accommodate both continuous and categorical variables, does not make prior assumptions regarding the influence direction of the categorical variable.

Following this approaches, studies by Jema and Andersson (2006); Hassen *et al.* (2012), Awol (2014), Sisay *et al.* (2015), Musa *et al.* (2015),Meftu (2016) and Kifle *et al.*(2017) used Tobit model, whereas Sharma *et al.* (1999),Arega (2003) and Getachew (2017) applied OLS method. In this study, two-stage estimation approach using SFA to estimate the levels of TE,AE and EE and Tobit model was applied to identify factors that affect technical, allocative and economic efficiencies of smallholder wheat farmers in the study area.

Many empirical studies showed that a range of firm- specific characteristics, institutional and socio-economic factors that causes efficiency variation. The significance of these factors can be analyzed using the following efficiency effect model (Battese and Coelli, 1995):

$$\mu i = \delta izi \tag{2.13}$$

Where:

μ_i −Denotes the efficiency of the ith firm and is assumed to be a function of farm specific socio-economic and farm management practices.

z_i −Stands for vector of firm specific variables which affect the efficiency of the i^{th} firm;

δ −Denotes a vector of parameters to be estimated;

Aigner *et al.* (1977) proposed the log likelihood function for the model on the equation (2.13) by assuming half-normal distribution for u_i and normal distribution for (v_i) and using lamda(λ) parameterization to express the likelihood function, where, λ is the ratio of the standard errors of the non-symmetric to symmetric error terms$(\lambda = \frac{\sigma_u}{\sigma_v})$. However, due to the reason that λ could be any non-negative value while γ ranges from zero to one that measures the distance between the frontier output and observed output and basically separates the effects of noises from inefficiency (Battese and Corra, 1977). Accordingly, the maximum likelihood estimates of the parameters of the frontier model were estimated from the log-likelihood function expressed in terms of gamma(γ) parameterization as follows:

$$\ln(L) = -\frac{N}{2}[\ln[\frac{\pi}{2}] + \ln\sigma^2] + \sum_{i=1}^{N} \ln[1 - \varphi[\frac{\varepsilon i\sqrt{\gamma}}{\sigma^2}\sqrt{\frac{\gamma}{1-\gamma}}]] - \frac{1}{2\sigma^2}\sum_{i=1}^{N} \varepsilon i^2 \quad (2.14)$$

Where:

$L =$ Represent likelihood function

$\varepsilon i = lnY - X_i\beta$ −Represent composed error term;

$N -$ Represent the number of observations;

$\Phi(.)$ −Represent the standard normal distribution;

$\sigma^2, \gamma -$ Represent the variance of parameters of the model and

$\gamma = {\sigma^2}_u / {\sigma^2}_v + {\sigma^2}_u$

σ_u^2- is the variance parameter that denotes deviation from the frontier due to inefficiency; σ_v^2 - is the variance parameter that denotes deviation from the frontier due to noise.

Where the γ parameter has a value between 0 and 1. A value of γ of zero indicatesthat thedeviations from the frontier are entirely due to noise, while a value of one would indicate thatall deviations are due to technical inefficiency.Minimization of the function on equation (2.14) with respect to the parameters($\beta, \sigma^2\gamma$) and solving simultaneously the first partial derivatives of the function by equating to zero produces the efficient maximum likelihood estimates of the parameters.

The maximum likelihood estimates of the stochastic frontier and efficiency parameter was computed using STATA version 13.

2.5. Review of Empirical Studies on Efficiency

2.5.1. Studies within Ethiopia

Getahun and Geta (2016) employed the stochastic frontier with translog functional form with a one-step approach to assess technical efficiency and factors affecting efficiency in wheat production. They found a mean technical efficiency score of 57%. Sex, age and educational level of the household head, livestock holding, group membership, farm size, fragmentation, tenure status and investment in inorganic fertilizers positively affected technical efficiency, and distance to all weather roads affected TE negatively. The finding implies presence of an opportunity to improve technical efficiency among the farmers by 43% through gender-sensitive agricultural intervention, group approach extension, and attention to farmers' education, and scaling out of best farm practices.

Hassen (2016) employed stochastic production frontier to measure the level of technical efficiency and identify its determinants in wheat crop production of smallholder farmers in south Wollo zone, Ethiopia. He used a multi-stage sampling technique to select 68 wheat growing sample households. The Stochastic Production Frontier result revealed that area allocated under wheat, seed, fertilizer applied and labor in man days were appeared to be significantly influencing wheat production. The average technical efficiency was 78% while return to scale was 1.17% implying that farmers are operating at an increasing return to scale. His result indicated as there is a potential for increasing wheat output by 22% with the existing levels of inputs and technology. The result showed that factors such as age, education, access to credit, and oxen number were negatively affected inefficiency while number of livestock and distance to market were positively affected inefficiency.

Assefa (2016) estimated the technical efficiency of smallholder wheat producers and identified its determinants in Soro district of Hadiya zone, Southern Ethiopia using Cobb-Douglas stochastic production frontier model. He used cross sectional data from a randomly selected sample of 125 wheat producing farmers collected during 2015/16 production season and applied one stage estimation method. The average technical efficiency score was 72%. The estimated stochastic production frontier (SPF) model together with the inefficiency parameters shows that age and education level of household head, land ownership, fertility status of the wheat plots and extension contact have negative effects on technical inefficiency of wheat production implying that improvement in these variables improves technical efficiency. However, land fragmentation has positive and significant effect on technical inefficiency.

Awol (2014) conducted study on economic efficiency of rain-fed wheat producing smallholders farmers in North Eastern Ethiopia using cross-sectional data obtained from 120 randomly selected farmers in 2012 production year. He used Cobb-Douglas stochastic production frontier model to estimate technical, allocative and economic efficiency levels, and Tobit model to identify factors affecting efficiency levels. The SPF model indicated as there is significant inefficiency in wheat production in the study area. Accordingly, mean indices of technical efficiency (TE), allocative efficiency (AE) and economic efficiency (EE) were 72.49, 42.7 and 31.65% respectively. This implies that output can be increased by 27.51% or cost can be reduced by 57.3% given the existing level of technology and resources. The result of Tobit model indicated that sex of the household head, land fragmentation, fertility status, slope of land, credit use, training obtained, and oxen numbers affected TE positively and significantly, while it is negatively affected with farm size. The AE and EE of the farm household was positively and significantly affected by sex of the household head, frequency of extension use, oxen number, family size, plot slope and training. On the contrary, age of the household head and number of livestock unit have negative effect on AE and EE level.

Tolesa *et al.*(2014) studied smallholder wheat technical efficiency in the three agro ecologies of East Arsi zone. Cross sectional data collected from 381 randomly selected farm households for 2012/13 cropping season was used to identify the levels of technical efficiency and sources of inefficiencies. A Cobb-Douglas production function with stochastic frontier analysis were employed. The study found considerable variation in technical efficiency among agro-ecologies and within agro-ecology. The mean technical efficiency estimates for lowland, midland and highland agro-ecologies were 57, 82 and 78%, respectively. The technical efficiency ranges from 24.4 to 88.6% in the lowland, 51.6 to 94.4% in the midland, and 34.5 to 94.3% in the highland agro-ecologies. This shows that smallholder farmers were inefficient in wheat production in the study area. Technical inefficiency is negatively affected by age, education, livestock size, crop rotation and row planting, and positively by family size, improved seed and access to credit.

Study conducted on economic efficiency of wheat seed production among smallholder farmers in West Gojjam zone by Solomon (2012) used Cobb-Douglas stochastic production frontier model to estimate the three levels of efficiency. He also employed Tobit model to identify factors affecting efficiency levels. The study indicated as there is significant inefficiency in wheat seed production in the study area. Accordingly, the mean technical, allocative and economic efficiencies of sample households were 79.9, 47.7 and 37.3%, respectively. Tobit model revealed that interest in wheat seed business and total income positively and significantly affect technical efficiency while total expenditure has negative and significant effect on TE. Livestock ownership and educational level have a significant positive effects and participation in share cropping and total cultivated land have a significant negative effects on allocative and economic efficiencies respectively.

Essa *et al.* (2012) assessed farm-level resource use efficiency in the production of wheat, teff and chickpea using a cross sectional data obtained from 700 rural households in the central highland of Ethiopia. The Data Envelopment Analysis (DEA) results show that smallholder farmers are resource use inefficient in the production of major crops with mean technical, allocative and economic efficiency levels of 74, 68 and 50%, respectively. A Tobit model regression results on the determinants of inefficiency reveal that livestock ownership and participation in off-farm activities reduced level of resource use inefficiency. Furthermore, large family size and membership to associations contribute to higher level of resource use inefficiency.

2.5.2. Studies outside Ethiopia

Muhammad *et al.(*2015) conducted study on technical efficiency and its determinants in wheat production in the case of Southern Punjab, Pakistan. They used DEA to measure the level of technical efficiency, based on the cross sectional data collected from 148 randomly selected farmers. Input oriented TE has been considered in their study, since farmer was the decision maker who has control over input(s) but not over output(s). The estimated technical efficiency ranges between 47 and 100% with a mean of 73.6%. The results showed that age, experience, farm size, farm type and agricultural farm machinery has a significant positive effect on technical efficiency. Moreover, wheat farm size has significant and negative effect on TE i.e. farmers with small farms are more efficient than large farm size.

Harish and Vanita (2013) used Cobb-Douglas stochastic production frontier to analyze technical efficiency in wheat production in the case of Amravati division of Vidharbha region of Maharashtra state, India. They used cross sectional data collected from a sample of 81 wheat farmers. Their study result revealed that the level of technical efficiency of wheat production ranges from 66 to 96% with mean of 85%, indicating the presence of 15% inefficiency. It implies that there is a possibility to increase the productivity of the farmers to the extent of 15%. This means that there are substantial opportunities to increase productivity and income through more efficient use of productive resources.

Ali *et al.* (2012) assessed economic efficiency of wheat and faba bean production for small scale farmers in northern state of Sudan. They used translog production function with stochastic frontier to estimate the economic efficiency of wheat and faba bean production, based on cross sectional data collected from 120 randomly selected farmers from Dongola locality in the north and Ed-abba locality in the south of the state. The result showed that the mean technical efficiencies of wheat were 75 and 66% in Dongola and Ed-abba, respectively, while for faba bean they were 65 and 71%, the overall mean allocative efficiencies of wheat in the two localities were 72 and 68%, whereas, 86 and 84% for faba bean respectively. The predicted overall mean of economic efficiencies of wheat were 41 and 45% in the two localities, while in faba bean production 57 and 62% in Dongola and Ed-abba, respectively. It indicates that the EE of faba bean is better than wheat.

Benjamin *et al.* (2011) examined the economic efficiency of small scale farmers in Benue state, Nigeria with a view to examine the economic efficiency of Nigerian small scale farmers. They collected a data from 393randomly selected farmers, and analyzed using descriptive statistics, stochastic frontier production and cost function models. The return to scale for the production function revealed that the farmers were operated in the irrational zone (stage I) of the production surface having return to scale of 1.58. The increasing return-to-scale in their study implies increasing productivity per unit of input, suggesting that the farmers are not using their resources efficiently. They obtained the mean values of technical, allocative and economic efficiency of 30, 12 and 36% respectively, indicating that the sample farmers were inefficient in allocating their limited resources. Their result showed that, technical and allocative inefficiency is negatively affected by age, education, farming experience, household size, dependency ratio, access to extension and household distance to the nearest city. Household distance to the nearest urban market positively affect both technical and allocative inefficiency. Allocative inefficiency is also positively affected by household distance to the nearest tarred road.

In general, different studies used different models to analyze the efficiency of farmers and the influence of different agro-climatic and socio-economic conditions on farmers' performance. Therefore, undertaking studies on farm households' efficiencies in different localities help the policy makers and other development workers to design and implement an appropriate policy intervention. It was also indicated that a number of factors can affect the efficiency level of farmers, but those factors are not equally important and similar in all places at all time. A decisive factor in one place at certain time may not necessarily be a significant factor in other places or even in the same places after some time. Therefore, policy implications drawn from some of the above empirical works may not allow in designing area specific policies to be compatible with its socio-economic as well as agro-ecologic conditions.

In addition, the literature reviewed above prevails that there is limited work in area of allocative and economic efficiency, with special accent on wheat production in Ethiopia. Moreover, the stochastic frontier approach (SFA) is adopted to study efficiency of different sectors, indicating that it has wider application and is also appropriate to use for agricultural sector. Hence, this study adopted the most widely applicable method of estimating efficiency, SFA, in estimating technical, allocative and economic efficiencies of smallholder wheat producers and two-limit Tobit model to identify factors that determine efficiency of the sampled households in the study area.

2.6. Conceptual Framework of the Study

Conceptual framework is defined as a network or a plane of interlinked concepts that together provide a comprehensive understanding of a phenomenon. In other words, it is a visual that explains either graphically or in a narrative form, the main things to be studied (key factors, concepts, variables and the presumed relationships among them) (Miles and Huberman,1994).

Production process involves a transformation of inputs into outputs. Inputs as well as outputs vary from one type of production to another. In crop production, the major inputs include land, seeds, labor, fertilizer and oxen, which are all combined in different ratios to produce outputs. The effectiveness with which the inputs are transformed into outputs does not only depend on inputs used but also on the managerial practices that the farmer uses to combine these inputs. Studies by Jema (2008) showed that efficiency of production was determined by the host of socio-economic, demographic and institutional factors. These factors directly/indirectly affect the quality of management of the farm's operator and, therefore, are believed to have impact on the level of efficiencies. According to Bakhsh (2007), a range of factors such as distinctiveness of farms, management, physical, institutional and environmental aspects could be the cause of inefficiencies in the production process of the farmers.

Based on the different review of literature made above efficiency of smallholder wheat production is assumed to be affected by a wide range of factors. From the general reviews, the various factors can be grouped as: (a) socioeconomic characteristics (b) demographic characteristics (c) institutional factors and (d) farm characteristics. The factors related to the socioeconomic characteristics include off/non-farm income, livestock holding and educational level of the household head. The factors related to demographic characteristics include age, sex and family size. The factors related to farm characteristics are farm size, land fragmentation and soil fertility. The institutional factors include credit utilization, distance from the nearest market and extension service.

Managerial practices are influenced by socio-economic, demographic, farm characteristics and institutional factors, which together with the inputs determine the quality and quantity of outputs produced. Households are the decision making units where all decisions on types and amounts of inputs to be used in production process and managerial practices to be done are made. The decisions made in turn influence how inputs are efficiently transformed into outputs. This situation is represented in a pictorial form as follows to guide this study.

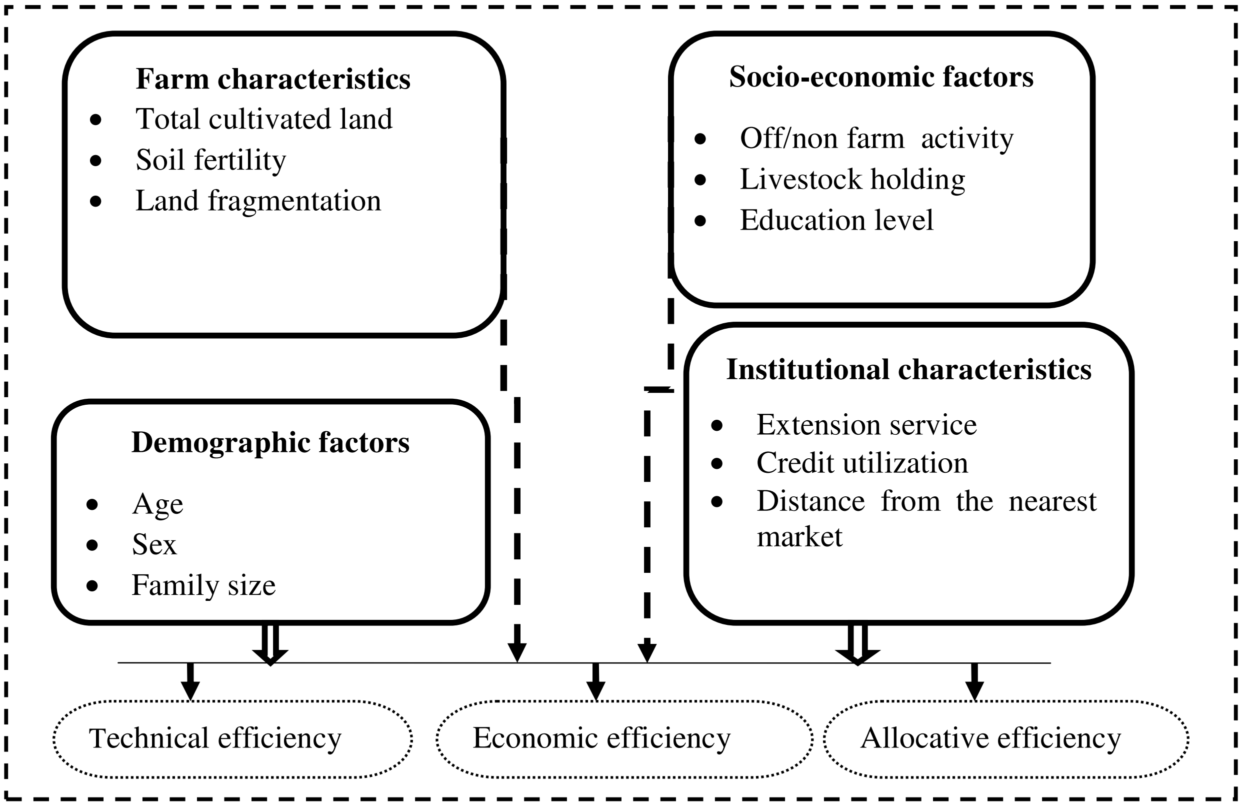


Figure 3: Conceptual framework of the study.

Source :Adopted from Kifle *et al.*(2017) and based on the above empirical reviews

3. RESEARCH METHODOLOGY

In this chapter, the study area and the research methodology followed are briefly explained. Besides, the definition and hypothesis for input and efficiency variables are clearly described.

3.1. Description of the Study Area

Abuna Gindebarat district is located in West Shewa Zone, Oromia National Regional state in the Western part of Ethiopia. It is located at 184 Kmwest of the capital city of the country, Finfinne. It is bordered by Meta Robi district in East, Gindebarat district in West, Jeldu district in South and Amhara National Regional State in North. The district has 42 rural kebeles[1] administrations and 2urban kebeles. The total area of the district is138,483.25 ha, of which annual crops cover 87,784.25 ha and the remaining land is allocated for grazing, forest and other purposes. The annual rainfall of the study area ranges from 700-2400mm with an annual temperature of 10-30^{0}C. The study area has total population of 126,996of which 47.2% are male and 52.8% are female. Moreover, among these 95.84 and 4.16% live in rural and urban areas respectively (AGDANRDO,2017).

Livelihood of the population of the study area generally depends on rain fed agriculture and characterized by mixed crop-livestock farming systems where both crop and livestock production play a central role in the lives of the farming community. Crop production is one of the main activities in the district and is dominated by smallholder farmers practiced primarily under rain-fed farming system with traditional farming techniques. The main staple food crops grown around the study area are cereals such as teff, wheat, maize, sorghum; pulse and oil crops such as linseed, bean, Niger seed (nug); and horticultural crops such as pepper, tomato, Irish potato, sweet potato and sugarcane. Annual crops especially cereals are predominant and rain-fed agriculture is mainly practiced using animal draught power.

Livestock production is also one of the major economic bases in the district next to crop production. Community pasture and straw from crops are the main sources of feed for livestock

[1]Kebele is the lowest administrative unit under Ethiopian condition.

production. The major livestock in the study area are cattle, sheep, goats, horses, donkeys, mules and poultry.

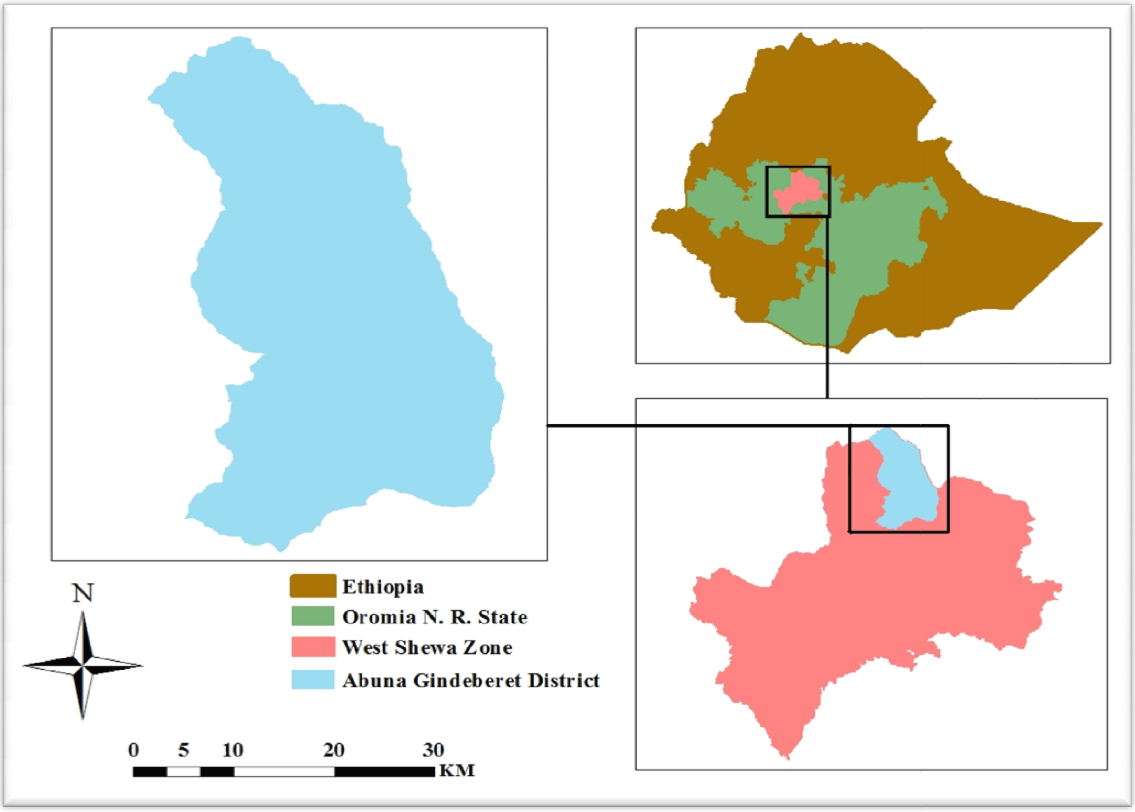


Figure 4:Location map of the study area

Source: Ethio-GIS, 2017

3.2. Sampling Technique and Sample Size Determination

Two stages random sampling procedures was employed to draw a representative sample. In the first stage, three kebeles out of the fifteen wheat producing kebeles in the district were randomly selected. In the second stage, 152 sample farmers were selected using simple random sampling technique based on probability proportional to the size of wheat producers in each of the three selected kebeles. To obtain a representative sample size, the study employed the sample size determination formula given by Yamane (1967) as follow:

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

Where:

n −Denotes sample size;

N −Denotes total number of wheat producing household heads in the district (5,344) and

e −Denotes the desired level of precision (taking 8%)

Table 1: Distribution of sample households by kebele

Name of Kebeles	Wheat producing households	Sampled households
Gitire	240	25
Jammo fenno	402	41
Erjajo	834	86
Total	1476	152

Source: Sampling design (2018)

3.3. Types of Data and Methods of Data Collection

This study used both qualitative and quantitative data. Both primary and secondary data sources were used. The primary data were collected using structured questionnaire that was administered by the trained enumerators. Enumerators who were capable of speaking the local language as well as English to explain the prepared question in the local language were hired and trained to collect the data. The questionnaire was pre-tested and necessary corrections were made before actual use. During interview, the researcher as well as respective enumerators provided enough information about the objectives of the study to avoid potential bias from the sample households in responding to questions. Moreover, local measurement scales customarily used by farmers was converted into their respective standard units. This helps to minimize measurement errors that could arise from variability of local units. Secondary data were also collected from relevant sources such as bureau of agriculture of the district and other relevant sources.

3.4. Method of Data Analysis

To address the objectives of the study, both descriptive statistics and econometric methods of data analysis were employed. Accordingly, descriptive statistics such as mean, maximum, minimum, standard deviation, frequency and percentage values of variables were computed to characterize the socioeconomic, demographic, institutional and farm characteristics of the sampled household heads in the study area. In addition, a stochastic frontier approach was used to estimate the level of efficiencies and two-limit Tobit model was employed to identify factors that affect the efficiency level of the farmers, in the econometric analysis. This is because, in the context of developing country where random errors (measurement error, weather and natural disaster) are common, stochastic frontier production function is a relatively better measure of efficiency (Coelli, 2005). Moreover, a two-limit Tobit model was applied to identify factors that affect the efficiency level of the farmers, because the model is more appropriate when the dependent variable (efficiency score) is bounded between 0 and 1 (Greene, 2003).

3.4.1. Efficiency measurement

Estimating the levels of technical, allocative and economic efficiencies and identifying determinants of technical, allocative and economic efficiencies of the sampled smallholder farmers in wheat production were the primary objectives of this study.

To address these objectives, the study employed the stochastic frontier model with Cobb-Douglas production function to assess the level of technical, allocative and economic efficiencies of wheat producing farmers in the study area. This model was autonomously developed by Aigner *et al.*(1977) and Meeusen and Van den Broeck (1977). It was used because of its key features that the disturbance term is composed of two parts, symmetric and a one sided component. The symmetric component captures the random effect beyond of the control of the decision maker including statistical noise (such as weather, topography, and measurement error), which are uncontrolled and exogenous to the farmer contained in every empirical relationship, particularly those based on cross-sectional household survey data. The one sided component captures deviations from the frontier due to inefficiency. Besides, the technique is consistent with most of the agricultural production efficiency studies (Olarinde *et al.,* 2008). Hence, economic efficiency measures obtained from stochastic frontiers are expected to reflect the true ability of the farmer with the given scarce resources and technology.

Moreover, most empirical studies on efficiency in Ethiopia analyzed using Cobb-Douglas stochastic production frontier (Jema, 2008; Endalkachew, 2012; Musa *et al.,* 2015; Awol, 2014; Tolesa et *al.,* 2014; Magnar and Alamirew, 2014; Sisay *et al.,* 2015; Kifle *et al.,* 2017; Mustefa *et al.,*2017; Nigusu, 2018). The main reason was stochastic approach allows for statistical noise arise from measurement errors and drought which are beyond the control of the decision making unit. However, some authors like Essa *et al.* (2012) and Geta *et al.* (2013) used DEA approach to measure efficiency level and source of efficiency variation among smallholder farmers.

However, the assumption that all deviation from the frontier are associated with inefficiency, as assumed in DEA, is difficult to accept, given the inherent variability of agricultural production due to a lot of factors like weather, pests, diseases, etc (Coelli, 1995). Furthermore, smallholder farmers in Ethiopia in general and in the study area in particular are characterized by low level of education and keeping of records is thus non-existent. Moreover, there is high variability of agricultural production due to weather fluctuations.

Therefore, within the stochastic frontier framework, the stochastic efficiency decomposition methodology was chosen as more appropriate for efficiency analysis. The stochastic frontier approach has been preferably applied in many agricultural economics studies (Coelli, 1995). Therefore, this study, employed stochastic production frontier to estimate the technical, allocative and economic efficiency levels of smallholder wheat producing farmers in the study area.

Following Aigner *et al.* (1977) the specified stochastic production frontier (SPF) model was defined as follows:

$$\ln(Y_i) = F(X_i, \beta_i) + v_i - \mu_i \quad i = 1,2,3 \ldots n \tag{3.2}$$

Where:

$i -$ Denotes the number of sample households

$\ln(\text{Yi}) -$ Denotes the natural log of (scalar) output of the i^{th} household;

$f(X_{i,} \beta)$ isa convenient frontier production function (e.g. Cobb-Douglas);

X_i − Represent a vector of input quantities used by the ith household

β_i −Denotes a vector of unknown parameters to be estimated

v_i- is a symmetric component and permits a random variation in output due to factorsbeyond the control of the decision making unit such as weather, omitted variables and other exogenous shocks. It is assumed to be independently and identically distributed $N\sim\ (0, \sigma^2{}_v)$and

μ_i-intended to capture inefficiency effects in the production of wheat measured as the ratio of observed output to maximum feasible output of the i^{th}farmer. It was assumed to be independently and identically distributed as half-normal, $u{\sim}N\ (u, \sigma^2{}_u)$.

One of the requirements of stochastic frontier functional approach was priori specification of the production function to estimate the level of efficiency. Among the possible algebraic forms, the most popularly used functional forms in many empirical studies of agricultural production analysis are Cobb-Douglas and translog functional forms. Many researchers argue that Cobb-Douglas functional form has an advantage over the other functional forms in that it provides a comparison between adequate fit of the data and computational feasibility. It is also very parsimonious with respect to degrees of freedom and it is convenient in interpreting elasticity of production.

In addition, the Cobb-Douglas production function is attractive due to its simplicity and because of the logarithmic nature of the production function that makes econometric estimation of the parameters a simple matter (Coelli, 1995). A logarithmic transformation provides a model which is linear in the logs of inputs and hence it lends itself to econometric estimation. Moreover, translog production function is more complicated to estimate the parameters having serious estimation problems. One of the estimation problem is as the number of variable inputs increases, the number of parameters to be estimated increases rapidly. Another problem is the additional terms require cross products of input variables, thus making a serious multicollinearity problems.

Even though the Cobb-Douglas production function model assumes unitary elasticity of substitution, constant production elasticity and constant factor demand; if the interest is to analyze the efficiency measurement and not analyzing the general structure of production function, it has adequate representation of technology and insignificant impact on measurement of efficiency (Coelli *et al.*, 2005). When farmers operate in small farms, the technology is unlikely to be substantially affected by variable returns to scale (Coelli, 1995). Moreover, many researches dealing with efficiency employed the Cobb-Douglas production function (Sharma *et a*l., 1999; Arega and Rashid, 2005; Jema, 2008; Hassen *et al.,* 2012; Berhan, 2015; Musa *et al.,* 2015; Sisay *et al.,* 2015; Gosa and Jema, 2016; Mustefa *et al.,* 2017; Kifle *et al.,* 2017 and Nigusu, 2018). Therefore, this study also tested whether to employ Cobb-Douglas or translog production functional form and the test result revealed as Cobb-Douglas production functional form best fits the data at hand. The linear form of the Cobb-Douglas production function for this study was defined as:

$$lnY_i = \beta_o + \sum_{j=1}^{5} \beta_j X_{ij} + v_i - u_i \qquad (3.3)$$

Where ln denotes the natural logarithm; j represents the number of inputs used; i represents the i^{th}farm in the sample; Yi represent the observed wheat output of the ith sample farmer; X_{ij} denotes j^{th} farm input variables used in wheat production of the i^{th} farmer; β stands for the vector of unknown parameters to be estimated; The symmetric component (vi) captures statistical noise and is assumed to be independently and identically distributed as $N\ (0, \sigma^2 v)$. On the other hand, μicaptures the technical inefficiency of the farmer and the distributional assumption of the technical inefficiency term.The variance parameters for Maximum Likelihood estimates are expressed in terms of the parameterization.

$$\gamma = \frac{\sigma_u^2}{\sigma^2} = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2} \qquad (3.4)$$

Where,

σ_u^2 is the variance parameter that denotes deviation from the frontier due to inefficiency

σ_v^2 is the variance parameter that denotes deviation from the frontier due to noise and

$\sigma^2$is the variance parameter that denotes the total deviation from the frontier

The value of γ measures the total variation of output from the production frontier which can be attributed to technical inefficiency (Battese and Cora, 1977). It ranges from 0 to 1, with values close to 1 indicating that the inefficiency component makes a significant contribution to the total variation of output from the production frontier (Coelli and Battese, 1996). If $\gamma = 0$, $\sigma_u^2 = 0$ and $\sigma_v^2 = \sigma^2$,it means that the farm outputs differ from frontier outputs due to measurement errors and other external factors of production beyond the control of the farmer. On the other hand, if $\gamma = 1$, $\sigma_v^2 = 0$ and $\sigma_u^2 = \sigma^2$, means that the difference between farm outputs and frontier outputs are due to farm inefficiencies.

In addition, the significance of σ^2indicates whether the conventional average production function adequately represent the data or not. In this study, to select the appropriate functional form that best fits the data, the likelihood ratio test was conducted with the hypothesis $(H_0 : \beta_{ij} = 0)$.

Following Greene (2003) the hypothesis tests were conducted using the log-likelihood ratio (LR) statistics, λ, which is defined in equation (3.5):

$$LR(\lambda) = -2ln[L(H_o)] - ln[L(H_1)] \quad (3.5)$$

Where:

$L(H_0)$ −Denotes the likelihood function value under the null (H_0)

$L(H_1)$ −Denotes the likelihood function value under alternative hypothesis(H_1)

This value is then compared with the upper 5% point for the X^2 distribution and the decision was made based up on the model result. If the computed value of the test is bigger than the critical value, the null hypothesis will be rejected and the translog frontier production function would better represent the production technology of farmers.

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

$$\ln(\text{output}) = \beta_0 + \beta_1 \ln(\text{seed}) + \beta_2 \ln(\text{land}) + \beta_3 \ln(\text{labor}) + \beta_4 \ln(\text{fertilizer}) + \beta_5 \ln(\text{oxen}) + vi - ui \quad (3.6)$$

Assuming that the production function in equation (3.6) is self- dual, the dual cost function of the Cobb-Douglas production function can be specified as:

$$\ln(C_i) = \beta_o + \sum_{j=1}^{5} \beta_j \, lnP_{ji} + \beta_j Y^* + v_i + u_i \qquad (3.7)$$

Where:

lnC_i −Denotes the (logarithm of the) cost of production of the i[th] firm;

P_{ji} − Denotes a vector of inputs price and output of i[th] firm;

β_o, β_j −Denotes a vector of unknown parameter to be estimated;

Y^*refers to wheat output.

v_i −Denotes random variables assumed to be independent and identically distributed random errors with zero mean and variance(σv^2) and

u_i −Denotes non-negative random variables which are assumed to account for cost inefficiency and assumed to be independent and identically distributed random errors with zero mean and variance(σu^2).

The farm-specific technical efficiency in terms of observed output (Yi) to the corresponding frontier output (Yi^*) using the existing technology was given as:

$$TE == \frac{Y_i}{Y_i^*} \qquad (3.9)$$

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

$$EEi = \frac{C^*}{C} \qquad (3.10)$$

Following Farrell (1957), the AE index will be derived from equations (3.9) and (3.10) as follows:

$$AEi = \frac{EEi}{TEi} \qquad (3.11)$$

3.4.2. Determinants of efficiency

In this study, to analyze the effect of demographic, socioeconomic, farm attributes and institutional variables on efficiencies, a second stage procedure was used where the efficiency scores estimated from stochastic production frontier was regressed on hypothesized 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, 1999). Estimation with OLS regression of the efficiency score would lead to a biased parameter estimate since OLS regression assumes normal and homoscedastic distribution of the disturbance and the dependent variable (Greene, 2003).

Following Maddala (1999) the model can be specified as:

$$y^*_{i\,TE,AE,EE} = \delta_0 + \sum_{n=1}^{12} \delta_n Z_{in} + \mu_i \qquad (3.12)$$

Where:

Where: i refers to the i^{th} farm in the sample households; n is the number of factors affecting technical, allocative and economic efficiency; y_i is efficiency scores representing the technical, allocative and economic efficiency of the i^{th} farm. y_i^* is the latent variable, δ_n are unknown parameters to be estimated and μ_i is a random error term that is independently and normally distributed with mean zero and common variance of $\sigma^2 \left(\mu_i \sim IN(0, \sigma^2)\right)$. Z_{in} are demographic, institutional, soci-economic and farm-related variables which are expected to affect technical, allocative and economic efficiencies.

Denoting yi as the observed variables,

$$y_i = \begin{bmatrix} 1 & if y_i^* \geq 1 \\ y_i^* & if 0 < y_i^* < 1 \\ 0 & if y_i^* \leq 0 \end{bmatrix} \qquad (3.13)$$

The distribution of dependent variable in equation (3.13) is not normal distribution because its value varies between 0 and 1. The ordinary least square (OLS) estimation will give biased estimates (Maddala, 1999). Therefore, the alternative approach is using the maximum likelihood estimation which can yield the consistent estimates for unknown parameters. Following Maddala (1999), the likelihood function of this model is given by:

$$L(\beta,\delta|y_{j,}X_jL_{1j,}L_{2j}) = \prod_{y_j=L_{1j}} \varphi\left(\frac{L_{1j}-\beta'X_j}{\delta}\right)\prod_{y_j=y_j^*}\frac{1}{\delta}\phi\left(\frac{y_j-\beta'X_j}{\delta}\right)\prod_{y_j=L_{2j}} 1-\varphi\left(\frac{L_{2j}-\beta'X_j}{\delta}\right) \quad (3.14)$$

Where $L_{1j}=0$ (lower limit) and $L_{2j}=1$ (upper limit) where $\varphi(.)$and $\phi(.)$are normal and standard density functions. In practice, since the log function is monotonically increasing function, it is simpler to work with log of likelihood function rather than likelihood function and the maximum values of these two functions are the same (Greene, 2003).

The regression coefficients of the two-limit Tobit regression model cannot be interpreted like traditional regression coefficients that give the magnitude of the marginal effects of change in the explanatory variables on the expected value of the dependent variable. In a Tobit model, each marginal effect includes both the influence of explanatory variables on the probability of 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 will have a simultaneous effect on probability of being technically, allocatively and economically efficient and value of technical, allocative and economic efficiency score. A useful decomposition of marginal effects that was extended by Gould *et al.* (1989) was proposed by McDonald and Moffitt (1980). From the likelihood function of this model stated in equation (3.14), Gould *et al.* (1989) showed the equations of three marginal effects as follows:

1) The unconditional expected value of the dependent variable:

$$\frac{\partial E(y)}{\partial x_j} = [\varphi(Z_U)-\varphi(Z_L)].\frac{\partial E(y^*)}{\partial x_j}+\frac{\partial[\varphi(Z_U-\varphi(Z_L)]}{\partial x_j}+\frac{\partial(1-\varphi(Z_U)}{\partial x_j} \quad (3.15)$$

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

$$\frac{\partial E(y^*)}{\partial x_j} = \beta_n.\left[1+\frac{\{Z_L\phi(Z_L)-Z_U\phi(Z_U)\}}{\{\{\varphi(Z_U)-\varphi(Z_L)\}\}}\right]-\left[\frac{\{\phi(Z_L)-\phi(Z_U)\}^2}{\{\varphi(Z_U)-\varphi(Z_L)\}^2}\right] \quad (3.16)$$

3) The probability of being between the limits

$$\frac{\partial[(\varphi(Z_U) - \varphi(Z_L)]}{\partial x_j} = \frac{\beta_n}{\sigma}.\left[\phi\,(Z_L) - \phi\,(Z_U)\right] \qquad (3.17)$$

where $\varphi(.) =$ the cumulative normal distribution, $\phi\,(.) =$ the normal density function, $Z_L = -\beta' X/\sigma$and $Z_U = (1 - \beta X/\sigma$ are standardized variables that came from the likelihood function given the limits of y^*, and σ =standard deviation of the model. The marginal effects represented by the equations above were calculated by the STATA command mfx which was complemented by specific options that allowed the estimation of marginal effects of change in explanatory variables.

3.5. Definition of Variables and Hypotheses

3.5.1. Production function variables

Wheat output (Y): This is the total amount of wheat produced expressed in terms of physical output of wheat in quintal (Qt) obtained by the sampled households during the 2016/17 production year. This is the dependent variable of the production function taken as continuous variable.

Seed: It is one of the inputs of wheat production which is the amount of local and improved wheat seed used to produce wheat in 2016/17 production year. It was included in the production frontier function in physical quantity and measured in kg.

Land: It refers to the total land area allocated by the sampled household for wheat production during 2016/17 production year measured in hectare. It was included in the production function as a continuous variable that includes owned, contracted and sharecropping lands.

Labor: It represents the aggregate labor (family, exchanged and hired) utilized in various farm activities(ploughing, sowing, harvesting and other agronomic practices)used for wheat production in 2016/17 production year and measured in man days.

Oxen power: Primarily oxen are used as a source of draught power in wheat production process in the study area. It refers to the number of draught power used for ploughing and threshing activities in wheat production during 2016/17 production year and it was measured in pair of oxen-days.

Fertilizer: It is the amount of mineral fertilizers(Nitrogen, Phosphorous and Sulphur (NPS) and Urea) applied for wheat production in 2016/17 production year. It was included in the production frontier function as continuous and measured in kilogram (Kg).

3.5.2. Cost function variables

Cost of labor: For hired labor the wage paid to the workers was recorded and for family labor (unpaid workers) it was estimated based on the wage paid to the hired labor in the district. Accordingly, the mean wage of labor estimated was birr 58 per man day.

Cost of seed: It is the price of seed in birr/kg used for wheat production in the study area. Hence, the average price of local and improved wheat seed were birr 7.25 and 16.12 per kg respectively. Accordingly, the average price of seed was 11.68 birr per kg.

Cost of land: Since, land do not have market price, rental price was used. For owned land the average rent paid in the district was taken and for rented-in land the amount paid was taken as its price. Accordingly the mean price were found to be 5,670 birr/ha.

Cost of oxen power: It was determined based on the rental price of pair of oxen power in the locality and its average price was birr 109 per oxen day.

Cost of mineral fertilizers: This was recorded as the market price paid to purchase mineral fertilizers (NPS and Urea) during 2016/17 production period. The average prices of NPS and Urea was birr 11.26 and 9.02 per kg respectively. Accordingly, the average price of fertilizer was 10.14 birr per kg.

3.5.3.Efficiency model variables and working hypotheses

These are variables hypothesized to explain the difference in production efficiency among farmers. These variables were selected based on previous studies and socioeconomic conditions of the study area.

3.5.3.1. Dependent variables

The dependent variables were: technical efficiency, allocative efficiency and economic efficiency scores of wheat producers obtained from stochastic frontier production function.

3.5.3.2. Independent variables

Based on previous studies on efficiency and socio-economic conditions of the study area, the following variables were expected to affect efficiency of sampled wheat producers.

Sex of the household head (SEXHH): It is a dummy variable that takes a value of 1 if the household head is male and 0, otherwise. Female-headed households may have less access to resources and information related to better production technologies than male-headed households. These are related to women's lack of control over economic resources and the nature of their economic activity. Since women were the one who were responsible for the many household domestic activities, they may not accomplish the farming activities on time and efficiently (Sisay *et al.*,2015). With this background including the existing gender differences, male headed households have more mobility, participate in different meetings and have more exposure to information about better farm inputs and practice (Sisay *et al.* 2015, Getahun and Geta, 2016). Therefore, it was hypothesized that male household heads were more efficient than female headed households.

Educational level of the household head (EDUCLHH): This is a continuous variable which was measured by the year of formal schooling of the household head. This is used as a proxy variable for managerial ability of the decision making unit. Education enables farmers to have access to new information, ideas, knowledge and skill to use resources in more efficient ways. Those farmers who are advanced in school level have better opportunity for agricultural production (Solomon, 2012; Getahun and Geta, 2016; Kifle *et al.,* 2017). Therefore, it was hypothesized that more educated household heads were more efficient than others.

Family size (FAMSIZ): It is a continuous variable and defined as total number of family members who lives in one roof (number of people living together and utilizing scarce resources) measured in man equivalent (ME); to capture the difference in age and sex. The family size was hypothesized to affect efficiency level of the farmers positively. This is because those households having a large number of family members have large number of family labor which is the main input in crop production. As a result, household that has large family size could carry out the required agronomic practices during production period on time. Empirical studies of Musa *et al.* (2015) and Sisay *et al.* (2015) also supports this hypothesis.

Livestock size (LIVESTSIZ): It is a continuous variable and defined as the total number of livestock owned by farmers measured in terms of Tropical Livestock Unit (TLU). This is used as a proxy variable for the wealth of the farmers. The cash from livestock sale can improve crop production through purchase of different inputs on time and they also produce manure that will be used to maintain soil fertility. Moreover, families with more animals are more likely to have larger protein intake than those with fewer animals, which helps to improve their working efficiency (Mekonnen *et al.*, 2015). According to empirical results of Solomon (2012), Tolesa *et al.* (2014) and Getahun and Geta (2016) livestock holding was found to positively affect efficiency. Therefore, since livestock's are source of income, which is used for purchase of inputs for wheat production, livestock size was expected to have positive effect on efficiency of wheat producers.

Credit utilization (CREDITU): It is a dummy variable that takes the value of 1 if the household head used credit for wheat production and 0 otherwise. Since, credit is an important source of financing the agricultural activities of smallholder farmers, it affects the ability of a farmer to obtain the necessary inputs at the right time and in suitable quantities. This is supported by empirical studies of Musa *et al.* (2015) and Kifle *et al.* (2017). Therefore, it was hypothesized that farmers who have used credit were more efficient than others.

Participation in off/non-farm activity (PONFAC): It is a dummy variable which takes a value of 1 if the household members participated in off/non-farm activity and 0, otherwise. Participation in off/non-farm activity could have positive effect on efficiency, because of the income obtained could be used for the purchase of agricultural inputs and augments for financing of household expenditures which would entirely dependent on agriculture. Empirical studies of Shumet (2011), Musa *et al.* (2015) and Solomon (2012) support positive and significant effect of off/non-farm activity on efficiency of production. Therefore, it was hypothesized that participation in off/non-farm activity positively affect efficiency of wheat producers in the study area.

Soil fertility (SOILFERT): It was treated as a dummy variable that takes a value of 1, if the household head perceives his/her plots as fertile and 0 otherwise, by considering that the soil with high fertility may have positive response to the fertilizer application. The more the land is fertile, the better the gain will be (Abebayehu, 2011). In this study, soil fertility was not determined by analyzing the soil samples. Farmers were asked to categorize their land as fertile and infertile as they know from their indigenous knowledge. Therefore, it was hypothesized that a farmer who allocated a fertile land for wheat production were more efficient than counterparts (Awol, 2014; Assefa, 2016).

Distance to the nearest market (DTNMRKT): It is defined as the distance of farmers home from the nearest market. It was a continuous variable measured in walking minutes. When farmers are located far from the nearest market, there would be limited access to input and market information. In other words, a farmer house located far from the market incurs more costs to transport farm inputs from the market, compared to the one closer to the market. Therefore, it was hypothesized that higher distance from the nearest market negatively affect efficiency of wheat producers. This hypothesis is supported by (Musa *et al.,* 2015).

Cultivated land (CLAND): It is a continuous variable which represents the total crop area in hectares managed by a farmer including owned, rented-in and cultivated through sharecropping arrangement. As the farm size of a farmer increases the managing ability of them will decrease given the current level of technology. In other words, farmers with small farm size was expected to be more efficient than those with large farm size because of its simplicity in management and less transaction costs (Jema, 2008; Otitoju and Arene, 2010). In addition, due to inappropriate input application and managing ability like ploughing and harvesting on time, farmers who cultivated large farms are less efficient than the other. Therefore, it was hypothesized that farm size negatively affect efficiency of wheat producers in the study area.

Age of the household head (AGEHH): It is a continuous variable, which refers to age of the household head measured in years. It is believed that, age of the household head can serve as a proxy to reflect experience and physical strength of the farmer. The implication is that as the age of the farmer increases, the farmer becomes more skilled in the method of production and optimal resource allocation. Thus, it was hypothesized that farmers with more years of age are expected to be more efficient than counterparts. This hypothesis is also supported by empirical studies of Mekdes (2011), Gosa and Jema (2016) and Getahun and Geta (2016).

Frequency of extension contact (FOEC): This variable serves as a proxy measure for access to extension services since all the extension user households may not get the services every time they need. It was a continuous variable measured by the number of visits made by development agents in relation to wheat production during cropping year. It was hypothesized that high frequency of contact with development agent positively affect efficiency. This is because, they have better access to information on new technology, recommended agronomic practices and market information that would productively used on their farm. Besides, it improves the human capital and management skill of the farmers. Therefore, it was hypothesized that high frequency of contact with development agent positively affect efficiency in the study area. This hypothesis is supported by (Assefa, 2016 and Getahun and Geta, 2016).

Land fragmentation (LANDFR): This is defined as the total number of plots that the household head had managed during 2017/18 production year. It was measured by number of plots the household head had handled during 2017/18 production period. Higher number of plots lead to reduce efficiency by creating shortage of family labor, wastage of time and other resources that should have been available at the same time (Wondimagegn, 2010). In addition, it is due to the fact that the farmer becomes less effective and less accessible to manage each plot if they are large in number and scattered. Hence, in this study, it was hypothesized as it have a negative effect on efficiency of farmers. This hypothesis is also supported by studies of Assefa (2016),Getahun and Geta (2016) and Mustefa *et al.*(2017).

4. RESULTS AND DISCUSSION

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

4.1. Descriptive Results

Before discussing results obtained from the econometric models, it is important to briefly present demographic, socio-economic, farm and institutional characteristics of the sampled farmers in the study area, since they affect the quality of the management of the farmer directly or indirectly and are believed to have effect on efficiency of production(Coelli and Battese, 1996). In addition, it would help to draw a general picture about the study area and sampled households.

4.1.1. Demographic and socio-economic characteristics of sample households

Age and family size: Age is one of the main factor which determine management experience of the farmers. The average age of the sample households during the survey period, was about 47.89 years. This implies that most of the household heads were within their productive age. The average family size of the sample households was found to be 6.12 man equivalents (Table 2).

Educational status: Education is a tool to enhance the quality of labor through improving the managerial skill and the tendency to adopt new technologies. Education together with increased experience could guide households to better manage their farm activities. According to the survey result, the average years of formal schooling of the sampled farmers was grade 5.82 (Table 2). In addition, besides to farm, off/non-farm activities are the source of income for rural households. The income they desperately need to obtain from such off/non-farm activity may substantiate the low income that is usually obtained from farming activities. According to the survey results, 67.76% of the sample households participated in off/non-farm activity (Table 3).

Livestock holding: In the study area, livestock has considerable role for household income and food security. They are used for draught power, food and cash income from selling their products. The type of livestock kept by sample farmers includes cow, oxen, horse, donkey, calf, sheep, heifer and hen. Among others, oxen power is the major input in crop production process serving as a source of draught power. On average, the livestock holding of the sampled farmers in the study area was 6.95 TLU (Tropical Livestock Unit)per household (Table 2).

Table 2: Descriptive statistics for continuous variables

Variables	Mean	Std. Dev.	Minimum	Maximum
Age of the household head (year)	47.89	10.05	24	75
Family size (ME)	6.12	1.8	2	11
Educational level of the household head (year)	5.82	3.04	0	12
Livestock holding (TLU)	6.95	3.17	1.68	15.15
Cultivated land (ha)	1.55	0.86	0.25	4.75
Frequency of extension contact(No.)	5.69	2.69	0	12
Distance to the nearest market (Min.)	32.97	13.32	3	55
Land fragmentation (No.)	2.08	0.85	1	4

Source: Own computation (2018)

With regards to the sex of respondents, the survey result shows, about 22.4% of the sample households were female headed and the remaining 77.6% were male headed households (Table 3). This implies most of the sample farmers are male headed.

4.1.2. Farm and institutional characteristics of sample households

4.1.2.1. Farm characteristics

Land is the primary and dependable means of living for the rural people of the country as a whole. The mean cultivated land owned by the sample farmers in the study area during the survey period was 1.55 ha(Table 2).The survey result also shows that, the average number of plots managed by the sampled households were 2.08 (Table 2).

4.1.2.2. Institutional characteristics

Institutional support services such as extension services, credit services and market accessibility are vital for growth of agricultural production. Extension services usually play a major role in disseminating new and improved farming techniques. The survey result showed that, about 96.05% of the farmers had contact with the development agents at least once during the cropping period. The average frequency of extension contact during the cropping season was found to be 5.69 (Table 2).

In the study area, Oromia Credit and Saving Share Company and Cooperative Bank of Oromia are the major formal sources of credit. The survey result shows, among the sampled farmers (89) 58.55% of sample households had utilized credit in the study area during the study year, 11 (7.24%) of them got their credit from formal sources while the remaining 78 (51.31%) households got it from informal sources like Idir and relatives. In addition, 63 (41.45)% of sample households are non-credit users in the study area (Table 3).

Besides, the survey result shows that, the average walking distance of the nearest market from the farmers residence during the survey period was 32.97 minutes (Table 2).

Table 3: Descriptive statistics for discrete variables

Variable	Frequency	%
Sex of the household head		
Male	118	77.63
Female	34	22.37
Credit		
Users	89	58.55
Non- users	63	41.45
Soil fertility status		
Fertile	112	73.68
Not fertile	40	26.32
Participation in off /non-farm activity		
Yes	103	67.76
No	49	32.24

Source: Own computation (2018)

4.1.3. Major crops grown

The major annual crops produced by the sampled households were wheat, teff, maize, barley, linseed, bean and Niger seed. On average, sample households allocated 0.712 ha (45.8%) of the total cultivated land for wheat production. Next to wheat, teff and maize were crops that took the largest proportion of the household's total cultivated land covering 0.495 and 0.098 ha, respectively. The sample households allocated 0.073 and 0.069 ha of the total cultivated land for barley and Niger seed, respectively. Moreover, linseed and bean were crops that took certain share of households total cultivated land covering, 0.067 and 0.039 ha, respectively (Table 4).

The survey result also demonstrates the average production of major crops in quintals. Given the difference in productivity among crops, sample households on average got 15.08 quintals of wheat which is 51.1% of total production. The total average production of teff was 7.5 qt (25.4%) of the total major crops production. Sampled households on average got 3.21 and 1.28 qt of maize and barley, respectively (Table 4).

Table 4:Average production of the major crops

Crop types	N	Area allocated (ha)		Production (Qt)	
		Mean	Percent	Mean	Percent
Wheat	152	0.712	45.8	15.08	51.1
Teff	133	0.495	31.8	7.5	25.4
Maize	50	0.098	6.3	3.21	10.9
Barley	37	0.073	4.7	1.28	4.3
Niger seed	15	0.069	4.5	0.8	2.7
Linseed	30	0.067	4.3	1.23	4.2
Bean	36	0.039	2.6	0.39	1.4

Source: Own computation (2018)

4.1.4. Inputs used for wheat production

Labor

Labor use is the indispensible element of wheat production activities in the study area. Sample farmers used family, hired and exchange labor to execute all activities of wheat production. According to the survey result, about 108 (71.05%) of the sampled household heads used only family labor whereas 15.13% of the sampled households employed work party (*Wonfel*) in addition to family labor to carry out all activities of wheat production. Furthermore, in addition to family labor,11.84% of the sampled households used hired labor whereas 1.97% of the household heads employed hired and work party labor for wheat production. On average, the sample farmers used 62.21 man days of labor for wheat production activities. Moreover, the average cost of labor used for wheat production was birr 3,644.37 (Table 6).

Oxen

Oxen were among the commonly used inputs for ploughing and threshing activities in the study area. Accordingly, the average pair of oxen used for wheat production activities by the sampled households during 2016/17 production season was 29.43 pair of oxen days. On average, the cost of oxen power used for wheat production was birr 3,217.05 (Table 6).

Land

Land plays an important role in farming as one of the most needed resource by the farmers to earn their livelihoods. Farmers have the right and practice of rent-in and/or rent-out land as well as to practice sharecropping. From the total of 236.38 ha of cultivated land with annual crops during 2016/17 production year by sample farmers, 108.25 ha of land is allotted for wheat production. From 108.25 ha of wheat land,87.68 ha (81%) was owned, 14% was contracted through sharecropping arrangement and 5% was acquired through rent (Figure 5). On average, sample households allocated 0.712 ha of land for wheat production. In addition, the average rental cost of land allocated for wheat by sample farmers was birr 4,037.44 (Table 6).

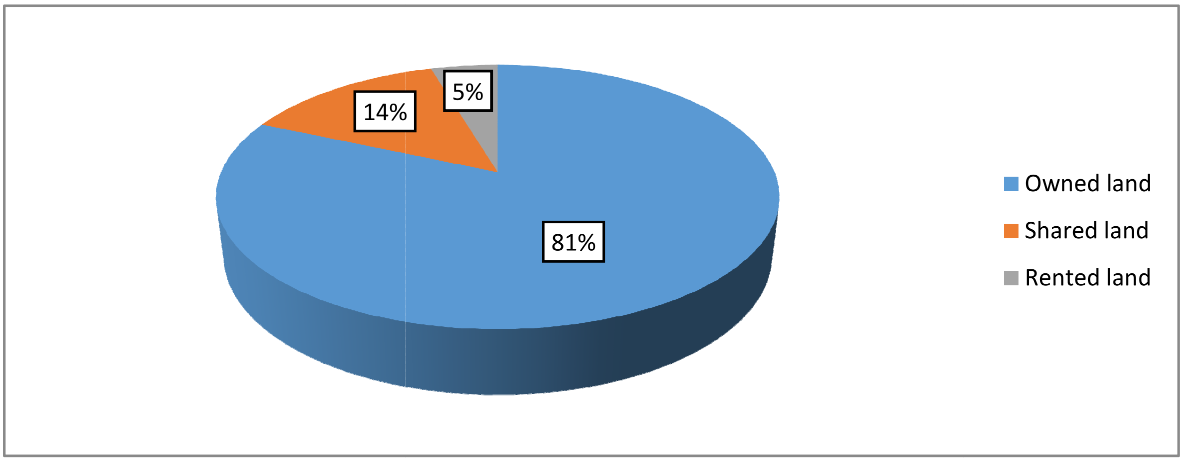


Figure 5: Land ownership of sample households

Source: Own sketch (2018)

Seed

In the study area, farmers sow both local and improved seeds. Accordingly, about 92.76% and 11 (7.24%) of sample farmers sowed local and improved wheat seed respectively. This indicates that most of the sample farmers utilize more of local variety than improved one. The main reason farmers are using local seeds than improved one is that because of the high price of improved seed. On average, the sample farmers used 122.75kg of wheat seed. Furthermore, the average cost of wheat seed used by sample farmers was birr 973.48 (Table 6).

Mineral fertilizers

Mineral fertilizers (NPS and Urea) are the most commonly used inputs for wheat production in the study area. The extension departments in the district recommends 1 to 1 ratio of NPS and Urea per hectare. This means they are recommending 100kg of NPS per hectare and 100kg of Urea per hectare of land. All sample farmers used mineral fertilizers for wheat production. But there was a variation in application rate.

According to the survey result, the sample farmers on average used 118.08 kg of mineral fertilizers. The price of mineral fertilizers was vary depending on distance from distribution center and duration of purchasing. The average cost of mineral fertilizers used by sample farmers was birr 1,240.15 (Table 6).

4.1.5. Production constraints

In the study area, the sample farmers reported as they faced production constraints. It is worth noting that there are multitude of problems related to weeds (*shebo*), high prices of pesticides, lack and high price of improved seeds, disease and low fertility of the soil coupled with shortage of rainfall. Late rains and early termination during sowing time and unexpected rains during harvesting time are rainfall related problems, which negatively affect crop production in the district. Sample respondents were asked to single out the most severe wheat production problem in their locality. Depending on the number of total responses, the major problems affecting wheat production in the study area were ranked as high price of improved seeds (34.87%), wild oat (*Avena fatua)* (*shebo*) (31.58%), low fertility of the soil (13.81%), disease (13.16%) and shortage of rainfall (6.58%) (Table 5).

Table 5:Major problems of wheat production

Problems of wheat production	Frequency	Percent
High price of improved seed	53	34.87
Wild oat (*shebo*)	48	31.58
Low fertility of the soil	21	13.81
Disease	20	13.16
Shortage of rainfall	10	6.58

Source: Own computation (2018)

4.1.6. Summary statistics of variables used in the models

The production function for this study was estimated using five input variables. The mean and standard deviation of input variables were summarized and presented in Table 6. On average, sample households produced 15.08 qt of wheat, which is the dependent variable in the production function. The land allocated for wheat production, by sampled households during the survey period was ranged from 0.125 to 2.5 ha with an average of 0.712 ha.

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 6. Among the various factors of production, the cost of land and labor accounted for the highest share 30.79 and 27.79%, respectively. Among other inputs, cost of seed took the smallest share 7.42 % out of the total cost of wheat production.

Table 6:Summary statistics of variables used to estimate the production and cost function

Variables	Unit	Mean	Std.Dev.	Min	Max
Output	Quintal	15.08	10.8	2	57
Seed	Kilogram	122.75	85.57	20.00	445
Land	Hectare	0.712	0.45	0.125	2.5
Labor	Man-days	62.21	37.4	10.00	215.6
Mineral fertilizers	Kilogram	118.09	82.9	20.00	525
Oxen	Oxen-days	29.43	15.62	5.00	81
Total cost of production	Birr	13,607.46	10,274.58	1,700	59,850
Cost of seed	Birr	9,73.48	900.65	131.25	6500
Cost of land	Birr	4,037.45	2,492.11	678.12	12000
Cost of labor	Birr	3,644.37	2,199.40	650	11858
Cost of mineral fertilizers	Birr	1,240.15	888.17	202.8	6037.5
Cost of oxen	Birr	3,217.05	1,767.18	475	11400

Source: own computation (2018)

The summary statistics of demographic, socioeconomic, farm and institutional variables which were expected to affect technical, allocative and economic efficiency levels of smallholder farmers in the study area are presented in table 7 below.

Table 7:Summary statistics of efficiency variables

Variables	Mean	Std. Dev.	Percentage of the mean with dummy = 0	Percentage of the mean with dummy = 1
Age of the household head (years)	47.89	10.05	-	-
Family size (ME)	6.12	1.80	-	-
Educational level (years)	5.82	3.04	-	-
Frequency of extension contact	5.69	2.69	-	-
Cultivated land (ha)	0.84	0.70	-	-
Livestock (TLU)	6.95	3.17	-	
Distance to the nearest market (min)	32.97	13.32	-	-
Land fragmentation	2.08	0.85	-	-
Sex of the household head	-	-	22.37	77.63
Fertility status of the soil	-	-	26.32	73.68
Credit utilization	-	-	41.45	58.55
Participation in off/non- farm activities	-	-	32.24	67.76

Source: own computation (2018)

4.2. Results of Econometric Analysis

In this section, the econometric results of the stochastic frontier and Tobit models were presented and discussed. In addition, the estimated efficiency scores and factors that affect efficiency of wheat producing sampled smallholder farmers were also discussed.

4.2.1. Hypotheses test

Before going on to the estimation of the parameters of the model from which individual level efficiencies are estimated, it is essential to examine various assumptions related to the model specification. In this study, three hypotheses were tested. Accordingly, the functional form that can best fit to the data at hand was selected by testing the null hypothesis which states that the coefficients of all interaction terms and square specifications in the translog functional forms are equal to zero (H_0: $\beta_{ij} = 0$) against alternative hypothesis which states that the coefficients of all interaction terms and square specifications in the translog functional forms are different from zero ($H_1: \beta_{ij} \neq 0$). This test was made based on the value of likelihood ratio (LR) statistics which could be computed from the log likelihood values of both the Cobb-Douglas and Translog functional forms using equation (4.1) below.

$$\lambda = -2[\log \mathrm{L}(\mathrm{H_o}) - \log \mathrm{L}(\mathrm{H_1})] \qquad (4.1)$$

The λ value computed by the above formula was compared with the upper 5% critical value of the χ^2at the degree of freedom equals to the difference between the number of explanatory variables used in both functional forms (in this case degree of freedom =15). Accordingly, the log likelihood functional values of both Cobb-Douglas and Translog production functions were -34.84 and -26.32 respectively. Therefore, the λ value computed was 17.04 and this value is lower than the upper 5% critical value of χ^2at 15 degree of freedom (24.9) (Table 8). This shows that the coefficients of the interaction terms and the square specifications of the production variables under the Translog specifications are not different from zero. As a result, the null hypothesis was accepted and the Cobb-Douglas functional form best fits the data.

Table 8: Generalized Likelihood Ratio test of hypotheses for parameters of SPF

Null hypothesis	df	λ	Critical value	Decision
$H_o: \beta_{ij} = 0$	15	17.04	24.9	Accept H_0
$H_o: \gamma = 0$	1	12.2	3.84	Reject H_0
$H_o: \delta_0 = \delta_1 = \delta_2 = \cdots \delta_{12} = 0$	12	77.56	21.03	Reject H_0

Source: Own computation (2018)

The second test is to test the null hypothesis that the inefficiency component of the total error term is equal to zero ($\gamma = 0$) and alternative hypothesis that inefficiency component different from zero. Thus, the likelihood ratio is calculated and compared with the χ^2 value at a degree of freedom equal to the number of restrictions (the inefficiency component) estimated by the full frontier, which is 1 in this case for all models.

As explained in Table 8, one-sided generalized λ test of $\gamma = 0$ provide a statistic of 12.2 for wheat production; which is significantly higher than the critical value of χ^2 for the upper 5% at one degree of freedom (3.84). Rejecting the null hypothesis implies that the average response function estimated by OLS, which assumes all farmers are technically efficient is an insufficient representation of the data, given the stochastic frontier and the inefficiency effects model. Consequently, the null hypothesis that wheat producers in the study area are fully efficient is rejected.

The third hypothesis tested was that all coefficients of the inefficiency effect model are simultaneously equal to zero (i.e.H_0: $\delta_0 = \delta_1 = \delta_2 = \cdots \delta_{12} = 0$) against the alternative hypothesis, which states that all parameter coefficients of the inefficiency effect model are not simultaneously equal to zero. The null hypothesis is to mean that the explanatory variables in the inefficiency effect model do not contribute significantly to the explanation of efficiency variation for wheat producing farmers. It was also tested in the same way by calculating the λ value using the value of the log likelihood function under the stochastic frontier model (without explanatory variables of inefficiency effects,H_0) and the full frontier model (with variables that are supposed to determine efficiency level of each farmer, H_1). Using the formula in Equation (4.1), the value obtained was 77.56, which is higher than the critical χ^2 value (21.03) at the degree of freedom equal to the number of restrictions to be zero (in this case the number of coefficients of the inefficiency effect model was 12). As a result, the null hypothesis is rejected in favor of the alternative hypothesis that explanatory variables associated with inefficiency effect model are simultaneously not equal to zero. Hence, these variables simultaneously explain the difference in efficiency among sampled farmers.

4.2.2. The MLE of the parametric stochastic production frontier

Given the specification of Translog, the Cobb-Douglas stochastic production was tested and found to best fit to the data and was used to estimate efficiency of farmers. The dependent variable of the estimated production function was wheat output (Qt) and the input variables used in the analysis were area under wheat (ha), oxen (pair of oxen-days), labor (man-days in man-equivalent), quantity of seed (kg) and quantity of fertilizer (Kg).

The result of the model showed that, among the five input variables considered in the production function, three variables (land, mineral fertilizers and seed) had positive and significant effect in determining the variation of wheat output(Table 9).

Land allotted for wheat production and mineral fertilizers are found to be statistically significant at 1% significance level implying that increasing the level of these inputs would increase wheat yield in the study area. Moreover, the coefficient for land use was 0.481, which implies that, at ceterius paribus, a 1% increase in the area of land allotted for wheat production, results in 0.48% increase in wheat output. Mineral fertilizers also appeared to be an important factor, with coefficient of 0.353. This implies that a 1% increase in mineral fertilizers enhance wheat output by about 0.35% at ceterius paribus. This result is consistent with the findings of Fekadu and Bezabih (2008), Tolesa *et al.*(2014), Sisay *etal.*(2015) and Hassen (2016). Similarly, the coefficient of production with regard to seed use was 0.179and significant at 5 % significance level. It is further indicated that, a 1% increase in the quantity of seed used for wheat production, holding all other inputs constant, results in 0.18% increase in wheat output. This result is also in line with the empirical results of Musa *et al.* (2015), Ermiyas *et al.* (2015), Getahun and Geta (2016), Mustefa *et al.* (2017) and Nigusu (2018).

The coefficients related with the inputs measure the elasticity of output with respect to inputs. The results showed that the input variables specified in the model had elastic effect on the output of wheat production. The scale coefficient calculated was 1.214, indicating increasing returns to scale. This implies that there is potential for wheat producers to expand their production because they are in the stage I production area. This implies that, a 1% increase in all inputs proportionally would increase the total production of wheat by 1.214%. Therefore, an increase in all inputs by 1%would increase wheat output by more than 1%. This result is consistent with the empirical results of Hassen (2016) and Assefa (2016) who estimated the returns to scale of 1.33 and 1.38% in the study of technical efficiency of wheat production in South Wollo and Hadiya zone, Ethiopia respectively.

Table 9:Estimates of the Cobb Douglas frontier production function

		MLE	
Variables	Parameters	Coefficient	Std. Err.
Intercept	β_0	0.561	0.560
lnseed	β_1	0.179**	0.076
lnland	β_2	0.481***	0.115
lnlabor	β_3	-0.091	0.098
lnfertilizer	β_4	0.353***	0.075
lnoxen	β_5	0.109	0.094
Variance parameters:			
$\sigma^2 = \sigma_v^2 + \sigma_u^2$		0.166***	
$\lambda = \sigma_u / \sigma_v$		1.451***	
Gamma (γ)		0.678	
Log likelihood		-34.84	

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

Source: Model output (2018)

The diagnostic statistics of inefficiency component reveals that sigma squared (σ^2) was statistically significant which indicates goodness of fit, and the correctness of the distributional form assumed for the composite error term. The estimated value of Gamma γ is 0.6778 which indicates that 67.78% of total variation in farm output from the frontier is due to technical inefficiency.

The dual frontier cost function derived analytically from the stochastic production frontier shown in table 9 is given by:

$$\ln C_i = 3.47 + 0.07\ln w_{1i} + 0.26\ln w_{2i} + 0.02\ln w_{3i} + 0.23\ln w_{4i} + 0.02\ln w_{5i} + 0.48\ln Y_i^*$$

Where C_i is the minimum cost of production of the i^{th} farmer, Y^*refers to the index of output adjusted for any statistical noise and scale effects and $w$stands for input costs.

4.2.3. Efficiency scores and their distribution

The model output presented in Table 10 indicates that the mean values of technical, allocative and economic efficiencies of the sample households were about 78.4, 80.9 and 63.5% respectively. This shows that sample households were relatively good in allocative efficiencies than technical and economic efficiencies.

The mean TE of sample farmers was about 0.78 with a minimum level of 0.29 and the maximum level of 0.95. This means that if the average farmer in the sample was to achieve the technical efficient level of its most efficient counterpart, then the average farmer could realize 17.12% derived from (1-0.784/0.946)*100 increase in output by improving technical efficiency with existing inputs and technology. This result is close to the results of Solomon (2012), Tolesa *et al.* (2014) and Awol (2014) who found the mean technical efficiency score of wheat production, 0.79, 0.78 and 0.72 in Gojjam, highlands of East Arsi and North Eastern, Ethiopia respectively.

In addition, the average AE of the sample farmers was about 0.80 with a minimum of 0.34 and a maximum of 0.98. This shows that farmers are not allocatively efficient in producing wheat and hence, a farmer with average level of allocative efficiency would enjoy a cost saving of about17.19% derived from (1 – 0.809/0.977)*100 to attain the level of the most efficient farmer. Similarly, the mean EE of the sample farmers was 0.63 implying 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 36.5% 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 36.5%. This low average level of EE was the total effect of both technical and allocative inefficiencies. The mean levels of efficiencies were comparable to those from other similar studies in Ethiopia. Accordingly, Nigusu (2018) found mean TE, AE and EE of 0.79, 0.83 and 0.66 respectively for teff producers in Northern Shewa, Ethiopia. In addition, Solomon (2012) found mean TE, AE and EE of 0.79, 0. 47 and 0.37 respectively for wheat seed producer farmers in West Gojjam, Ethiopia.

Table 10: Estimated technical, allocative and economic efficiency scores

Types of efficiency	Mean	Std.Dev.	Min	Max.
TE	0.784	0.090	0.289	0.946
AE	0.809	0.114	0.343	0.977
EE	0.635	0.109	0.099	0.911

Source :Model output (2018)

The distribution of the technical efficiency scores showed that about 47.36% of the sample households had technical efficiency score of 80 to 90%. But there were also some households whose technical efficiency score levels were limited to the range of 20 to 40%. On average, households in this cluster have a room to enhance their wheat production at least by 60%. Out of the total sample households, only 3.95% had technical efficiency score of greater than 90%. This implies that about 96.05% of the households can increase their production at least by 10% (Figure 6).The allocative efficiency distribution scores indicated that about27.63% of wheat producers operated above 90% efficiency level. The distribution of economic efficiency scores implies that 36.18% of the household heads have an economic efficiency score of 50-60%. This also indicates the existence of substantial economic inefficiency than technical and allocative inefficiency in the production of wheat during the study period in the study area (Figure 6).

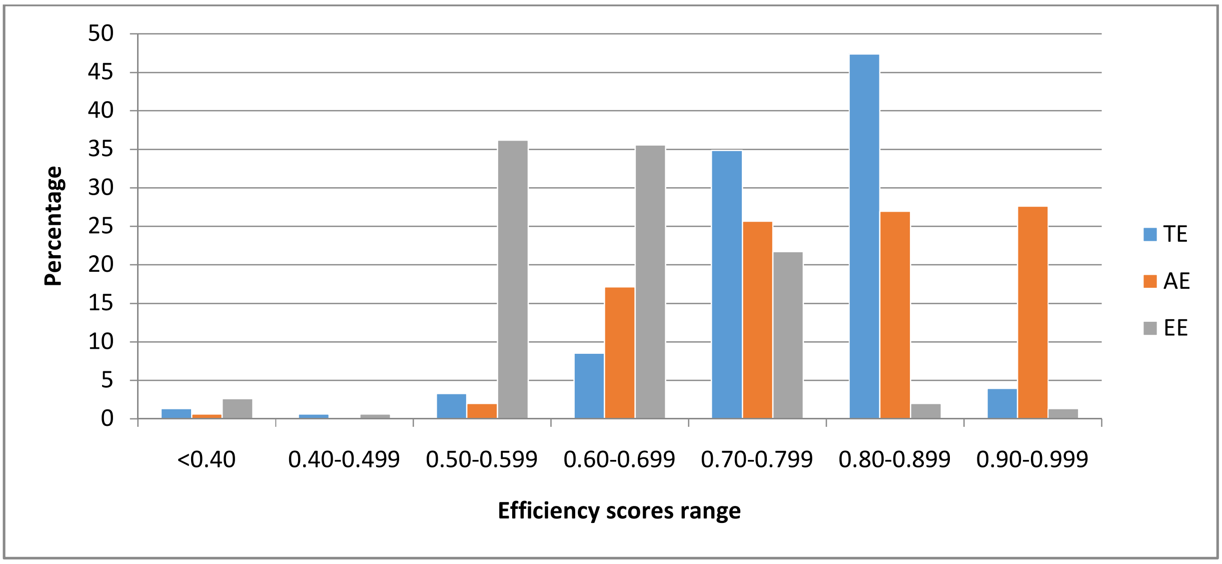


Figure 6: Frequency distribution of technical, allocative and economic efficiencies scores

4.2.4. Determinants of efficiency

After measuring levels of farmers' efficiency in wheat production and determining the presence of efficiency variation among farmers, finding out factors that affect efficiency levels among the sampled farmers was the next most important step of this study. To see this, the technical, allocative and economic efficiency levels derived from stochastic frontier were regressed on factors that were hypothesized to affect efficiency levels by using a two limit Tobit model. In this study, the dependent variable is efficiency scores not inefficiency. Thus, the marginal effect should be interpreted as their effect on efficiency and not inefficiency and if one wants to use inefficiency, the sign of the marginal effect, has to be changed.

The results of the Tobit regression model showed that among the twelve hypothesized variables six variables (sex of the household, education, extension, participation in off/ non-farm activity, soil fertility and land fragmentation) were found to be statistically significant in affecting the level of technical efficiency whereas four variables (age, education, extension and participation in off/non-farm activity) significantly influence allocative efficiency of wheat production. Moreover, the result of the model also discovered that six variables (age, sex of the household, educational level, frequency of extension contact, participation in off/ non-farm activity and soil fertility) were important factors in influencing economic efficiency of wheat producers in the study area (Table 11).

The finding of the study shows that age affected allocative and economic efficiency of the smallholder farmers in wheat production positively and significantly at 10 and 1% significance level, respectively. This implies that older farmers were more efficient than younger ones. This was probably because older farmers may have better experience in farming. Moreover, farmers at older age may accumulate good control of resources like oxen, farm tools and labor that could boost their efficiency, since in crop production, better availability of farm resources enhances timely application of inputs that increase efficiency of the farmer (Getachew and Bamlak, 2014). Furthermore, the computed marginal effect of age of the household head showed that, a one year increase in the age of the household head would increase the probability of the farmer being allocatively efficient by about 0.13% and the mean value of allocative and economic efficiency by 0.12 and 0.14% with an overall increase in the probability and the level of allocative and economic efficiencies by 0.14 and 0.14%, respectively. Similar positive and significant effect of age of the household head on efficiency was found by Ali and Abdel-Karim (2012), Getachew and Bamlak (2014) and Gosa and Jema (2016) in their respective studies. However, it contradicts with the findings of Shumet (2012) who found the negative effect of age on efficiency. Specific to this study, the relative difference might be because of older farmers have a large number of family size who can perform farm activities on time and this can enhance their efficiency.

The coefficient for sex of the household head was significant and positively affected technical and economic efficiencies of farmers at 1% significance level, as it was expected. It indicated male headed households operating more efficiently than their female counterparts. This implies, female household headed are the one who were responsible for many household domestic activities and also probably use inputs fewer than male household heads. Moreover, a change in the dummy variable sex from (0 to 1) would increase the probability of the farmers being technically and economically efficient by about 2.02and 0.002% and the expected value of technical and economic efficiencies by about 7.9 and 5.2% with an overall increase in the probability and levels of technical and economic efficiencies by 8.2 and 5.2%, respectively. This result is in line with the findings of Getahun and Geta (2016) and Meftu (2016) and it is in contrast with the study made by Mesay *et al.* (2013) who reported the negative effect of sex on efficiency in selected waterlogged areas of Ethiopia. Specific to this study, the comparative disparity might be because of male headed farmers have more access to information about agricultural production. In addition, if household heads are female, plowing, input application and threshing activities are performed by relatives or hired labor which affects timely operation of wheat production activities.

As expected, educational level of the household head had a positive and significant effect on TE, and AE at 5% and EE of wheat production at 1% level of significance. This is because education can increase their information acquisition and adjustment abilities, thereby- increasing their decision making capacity. In addition to this, it will help them to adopt modern agricultural technologies and be able to produce higher output using the existing recourses more efficiently. Moreover, educated households have relatively better capacity for optimal allocation of inputs. Additionally, the higher the level of formal schooling by farmers, the higher the allocative and economic efficiencies (Khan and Saeed, 2011). Moreover, the computed marginal effect revealed that, a one year increase in educational level of the household head increases the probability of a farmer being technically and allocatively efficient by 0.19 and0.59% and the mean values of technical, allocative and economic efficiencies by about0.44, 0.58 and 0.88% with an overall increase in the probability and levels of technical, allocative and economic efficiencies by 0.47, 0.66 and0.88%, respectively. This is because educated farmers could easily access information and use it to make well informed decisions. In line with this study, research done by Solomon (2012), Beyan *et al.* (2013), Sisay *et al.* (2015) and Musa *et al.* (2015) explains that the more educated the farmer, the more technically, allocatively and economically efficient s/he becomes.

The model result also indicated that soil fertility was positively and significantly affected technical and economic efficiencies at 1 and 5% level of significance, respectively. This implies that farmers who have allocated fertile land for wheat production were more technically and economically efficient than their counterparts. This may be associated with those fertile lands require less commercial fertilizer application which leads to reduction in cost and leads to reduction in the inefficiency of farmers. Moreover, a change in the dummy variable, fertility status of the soil from (0 to 1),would increase the probability of the farmer being technically and economically efficient by about 1.19and 0.001% and the expected values of technical and economic efficiencies by about 3.55 and 2.52% with an overall increase in the probability and levels of technical and economic efficiencies by 3.72 and 2.52%, respectively. This result is consistent with the empirical findings of (Fekadu and Bezabih, 2008; Awol, 2014; Ermiyas *et al.* 2015; Assefa, 2016).

Frequency of extension contact had significant and positive effect on technical efficiency at 5%, allocative and economic efficiencies at 1% significance level, respectively. This indicates households who receive more extension contacts by extension workers appear to be more efficient than their counterparts. That is, farmers who had more number of extension contact during the production year were technically, allocatively and economically more efficient than those who had less number of extension contact. Furthermore, the computed marginal effect result shows that, a unit increase in the number of extension contact would increase the probability of a farmer being technically, allocatively and economically efficient by 0.21, 1.44 and 0.001% and the mean values of technical, allocative and economic efficiencies by about 0.49, 1.40 and 1.71%with an overall increase in the probability and the level of technical, allocative and economic efficiencies by about 0.52, 1.60 and 1.71%, respectively. This result is similar with the findings of Beyan *et al.* (2013), Getachew and Bamlak (2014), Sisay *et al.* (2015) and Nigusu (2018) who found that farmers who had more number of visits with development agents enhanced their access to improved inputs and farming management practices thereby increased their production efficiencies.

It was hypothesized that a farmer participated in off/non-farm activity were more efficient than counterparts. As it was hypothesized the coefficient of participation in off/non-farm activity was positive and significant for technical and economic efficiency at 1% whereas allocative efficiency at 5% significance level. Participation in off/ non-farm activity affect efficiency positively for the reason that the income obtained from such activities could be used for the purchase of agricultural inputs, and may be because of the availability of off/non-farm income shifts the cash constraint outwards and enables farmers to make timely purchase of those inputs which they cannot provide from on farm income. Therefore, it enables farmers in maximizing their output at efficient cost of production. In addition, the computed marginal effect revealed, a change in a dummy variable participation in off/non-farm activity from (0 to 1), would increase the probability of the farmer being technically, allocatively and economically efficient by about 1.58, 2.90and 0.004% and the expected value of technical, allocative and economic efficiencies by about 4.46, 3.21 and 6.48% with an overall increase in the probability and levels of technical, allocative and economic efficiencies by 4.68, 3.63 and 6.48%, respectively. This result is in line with the empirical findings of Jema (2008), Solomon (2012) and Getachew and Bamlak (2014).

Table 11: Tobit regression results of determinants of technical, allocative and economic efficiency

Variable	TE		AE		EE	
	Coefficient	Std.Err	Coefficient	Std.Err	Coefficient	Std.Err
Constant	0.6402***	0.0461	0.5994***	0.0611	0.3656***	0.0423
AGEHH	0.0007	0.0006	0.0015*	0.0008	0.0014***	0.0005
SEXHH	0.0821***	0.0148	-0.0127	0.0196	0.0516***	0.0136
FAMSIZ	-0.0045	0.0033	0.0011	0.0044	-0.0027	0.0031
EDUCLHH	0.0048**	0.0022	0.0068**	0.0029	0.0088***	0.0020
CREDITU	-0.0003	0.0126	-0.0180	0.0168	-0.0185	0.0116
FOEC	0.0053**	0.0027	0.0166***	0.0035	0.0171***	0.0024
PONFAC	0.0472***	0.0136	0.0375**	0.0181	0.0648***	0.0125
CLAND	-0.0043	0.0086	-0.0025	0.0114	-0.0051	0.0079
SOILFERT	0.0375***	0.0137	0.0028	0.0182	0.0252**	0.0126
LIVESTSIZ	0.0012	0.0019	-0.0020	0.0025	-0.0003	0.0017
DTNMKT	-0.0006	0.0004	0.0003	0.0006	0.0001	0.0004
LANDFR	-0.0135*	0.0070	-0.0008	0.0093	-0.0082	0.0064

Note: *,** and *** refers to level of significance at 10, 5 and 1% respectively.

Source: Model output (2018)

The coefficient of land fragmentation for technical efficiency is negative and statistically significant at 10% significance level as it was expected. The result confirms the expectation, because fragmented land leads to reduce efficiency by creating lack of family labor, wastage of time and other resources that would have been available at the same time. Moreover, as the number of plots operated by the farmer increases, it may be difficult to manage those plots. Moreover, the computed marginal effect indicated, a unit increase in the number of plot would decrease the probability of a farmer being technically efficient by 0.55% and the mean value of technical efficiency by about 1.26%with an overall increase in the probability and the level of technical efficiency by 1.33%.This result is in line with the empirical results of Assefa (2016) and Mustefa *et al.*(2017).

Table 12:The marginal effects of change in explanatory variables

Variables	Marginal effects (TE)			Marginal effects (AE)			Marginal effects (EE)		
	$\partial E(y)$	$\partial E(y^*)$	$\partial[(\varphi(Z_U) - \varphi(Z_L)]$	$\partial E(y)$	$\partial E(y^*)$	$\partial[(\varphi(Z_U) - \varphi(Z_L)]$	$\partial E(y)$	$\partial E(y^*)$	$\partial[(\varphi(Z_U) - \varphi(Z_L)]$
AGEHH	0.00069	0.00065	0.00028	0.00143	0.00125	0.00129	0.00145	0.00145	0.00000
SEXHH	0.08161	0.07870	0.02020	-0.01222	-0.01062	-0.01182	0.05157	0.05157	0.00002
FAMSIZ	-0.00448	-0.00423	-0.00184	0.00107	0.00094	0.00096	-0.00275	-0.00274	-0.00000
EDUCLHH	0.00470	0.00444	0.00193	0.00659	0.00577	0.00593	0.00879	0.00879	0.00000
CREDITU	-0.00025	-0.00024	-0.00010	-0.01728	-0.01508	-0.01610	-0.01850	-0.01850	-0.00002
FOEC	0.00520	0.00491	0.00213	0.01600	0.01401	0.01441	0.01709	0.01709	0.00001
PONFAC	0.04681	0.04459	0.01577	0.03628	0.03215	0.02901	0.06484	0.06483	0.00004
CLAND	-0.00430	-0.00406	-0.00176	-0.00240	-0.00211	-0.00217	-0.00513	-0.00513	-0.00000
SOILFERT	0.03722	0.03550	0.01194	0.00271	0.00237	0.00241	0.02524	0.02524	0.00001
LIVESTSIZ	0.00123	0.00116	0.00050	-0.00194	-0.00170	-0.00175	-0.00033	-0.00033	-0.00000
DTNMKT	-0.00057	-0.00054	-0.00023	0.00026	0.00023	0.00024	0.00003	0.00003	0.00000
LANDFR	-0.01333	-0.01257	-0.00546	-0.00078	-0.00069	-0.00071	-0.00817	-0.00816	-0.00000

Note: $\frac{\partial E(y)}{\partial x_j}$ (Total change), $\frac{\partial E(y^*)}{\partial x_j}$ (Expected change) and $\frac{\partial[(\varphi(Z_U)-\varphi(Z_L)]}{\partial x_j}$ (change in probability).

Source: Model result.

5.SUMMARY,CONCLUSION AND RECOMMENDATIONS

5.1. Summary

Efficient production is the basis for achieving overall food security and poverty reduction objectives particularly in major food crops producing potential areas of the country. However, farmers are discouraged to produce more because of inefficient agricultural systems and differences in efficiency of production. The objective of this study was to estimate farm level efficiency and to identify factors affecting efficiency levels of smallholder wheat producers in Abuna Gindeberet district, Oromia National Regional State, Ethiopia. Qualitative and quantitative data types are used. The data were collected from both primary and secondary data sources. So that, the primary data was collected from sample respondents by using structured questionnaires. In this study, two stages sampling technique was employed to select 152 sampled household heads.

Descriptive statistics and econometric models were employed to analyze the data. Descriptive statistics like mean, minimum, maximum, percentage and standard deviation were used to summarize socioeconomic, demographic, institutional and farm characteristics of the sampled households. Econometric models like stochastic production frontier and two limit Tobit model were applied to achieve the objectives. Stochastic production frontier was used because of its key features that the disturbance term is composed of two parts, symmetric and a one sided component. The symmetric component captures the random effect beyond the control of the decision maker including statistical noise and the one sided component captures deviations from the frontier due to inefficiency. Two limit Tobit model was employed to identify factors affecting efficiency levels of the sampled farmers. 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 parameters.

The results of stochastic production frontier model indicated that land, mineral fertilizers and seed were positively and significantly affected wheat production. The study result also shows that there was significant amount of variation in efficiency among farmers. Accordingly, the mean values of technical, allocative and economic efficiencies were 78, 80 and 63%, respectively. A two-limit Tobit model result indicated that technical efficiency positively and significantly affected by sex of the household head, education, extension contact, participation in off/non-farm activity and soil fertility but negatively affected by land fragmentation. Similarly, age, education, extension contacts and participation in off/non-farm activity positively and significantly affected allocative efficiency. In addition, economic efficiency positively and significantly affected by sex, age, education, extension contact, participation in off/non-farm activity and soil fertility.

In general, the stochastic production frontier model showed that production can be improved by increasing the use of inputs. There is a considerable room to enhance the efficiency of smallholder farmers in wheat production in the study area. The implication is that, there will be considerable gain in production level or reduction in cost of production, if introduction and dissemination of agricultural technologies is coupled with improving the existing level of efficiency.

5.2. Conclusion

This study found that, there is a considerable room to enhance the level of technical, allocative and economic efficiency of wheat producing farmers in the study area. Result of the production function indicated that seed, land and mineral fertilizers were the significant inputs, with positive sign as expected. Among the three significant inputs, mineral fertilizers and land under wheat production had significant and positive influence on wheat production at less than 1% level of significance. This depicts that farmers who allocated more land for wheat production and those who applies more amount of mineral fertilizers receive higher wheat yields. The coefficients related with the inputs measure the elasticity of output with respect to inputs. The results showed that the input variables specified in the model had elastic effect on the output of wheat production. The coefficient calculated was 1.214, indicating increasing returns to scale This implies that, a 1% increase in all inputs proportionally would increase the total production of wheat by 1.214%. Therefore, an increase in all inputs by 1% would increase wheat output by more than 1% in the study area.

The estimated mean values of technical, allocative and economic efficiency levels were 78, 80 and 63%, respectively. This implied wheat producers in the study area are not operating at full technical, allocative and economic efficiency levels. In other words the result indicated that there is opportunity for wheat producers to increase wheat output at existing levels of inputs and minimize cost without compromising yield with present technologies available in the hands of producers.

The factors that affect efficiency of the sampled households were identified to help different stakeholders to boost the current level of efficiency in wheat production by using two limit Tobit model. Accordingly, education, extension and participation in off/non-farm activity had positive and significant effect on technical, allocative and economic efficiencies. This shows that more educated farmers, the more farmers have contact with extension agent and farmers participating in off/non-farm activities were more technically, allocatively and economically efficient than their counterparts respectively. In addition, as it was expected sex and soil fertility had positive and significant effect on technical and economic efficiencies, implying that male headed households, household heads who allocate fertile land for wheat production were more technically and economically efficient than their counterparts, respectively. Similarly, age had a positive and significant effects on allocative and economic efficiencies, which implies that older household heads were more efficient than their counterparts.

Moreover, land fragmentation had negative and significant impact on technical efficiency. This implies that household heads with small number of plots were more efficient than their counterparts.

5.3. Recommendations

The results of this study give information to policy makers on how to improve the TE, AE and EE efficiency and optimal use of resources in the study area. The following policy recommendations have been drawn based on the results of the study. First, using best practices of the efficient farmers as a point of reference would help setting targets in improving efficiency levels and finding the weakness of the present farm practices. The relatively efficient farms can also improve their efficiency more through learning the best resource allocation decision from others. This can be achieved by arranging field days, cross-visits, creating forum for experience sharing with elder households and on job trainings.

Age, used as a proxy for experience, showed a positive and significant effect on efficiency. This may be due to experience learnt over the years of farming activity. Therefore mechanisms should be devised to encourage farmers with little experience to work with the experienced ones or train them. This could be done via the Farmer Training Center (FTC) in which the experienced farmers are trained and let to diffuse their accumulated practices to the youngsters with less experience.

The results of the study also shows, as female household heads were less efficient than male household heads. This is may be due to female headed households are too busy with domestic activities and had less time to manage their farm plots. Thus, especial emphasis should have to given for female headed households by providing improved technologies that can help them in decreasing their home burden and this would in turn help them to improve their efficiency level in wheat production.

In the study area, education of household heads had positive and significant effect on technical, allocative and economic efficiencies. Hence, the key policy implication is that appropriate policy should be designed to provide adequate and effective basic educational opportunities for farmers in the study area. In this regards, the regional government should have a main responsibility to keep on providing basic education in these areas and facilitates the necessary materials so that farmers can understand agricultural instructions easily and have better access to information and use the available inputs more efficiently.

The result of the study indicated that extension contact has positive and significant effect on technical, allocative and economic efficiencies. Therefore, suitable and sufficient extension services should be provided for the farmers in the study area. This could done by manipulative appropriate ability building program to train additional development agents and to provide refreshment training for development agents.

The study also found that, participation in off/non-farm activity had a positive and significant effect on technical, allocative and economic efficiencies. This implies that financing timely and enough use of inputs through additional income generated by off/non-farm are critical. Therefore, strategies that enhance the ease use of off/non-farm employment opportunities would help to increase the timely and appropriate use of inputs for better efficiency in wheat production in the study area.

Moreover, technical and economic efficiency were positively and significantly affected by soil fertility. Therefore, improvement of the soil status by applying organic manures and practicing different soil conservation techniques should have to done by farmers. In addition, extension workers in the study area can play a great role in improving the soil status by working closely with the farmers.

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APPENDICES

Appendix table 1: Conversion factor used to calculate man equivalent and adult equivalent

Age groups (years)	Man Equivalent		Adult Equivalent	
	Male	Female	Male	Female
<10	0	0	0.6	0.6
10-13	0.2	0.2	0.9	0.8
14-16	0.5	0.4	1.0	0.75
17-50	1.0	0.8	1.0	0.75
>50	0.7	0.5	1.0	0.75

Source: Storck *et al.* (1991)

Appendix table 2:Conversion factors used to estimate Tropical Livestock Unit equivalents

No.	Animal category	TLU
1.	Ox and cow	1.0
2.	Sheep and goats (young)	0.06
3.	Sheep and goats (adult)	0.13
4.	Horse	1.1
5.	Donkey (young)	0.35
6.	Donkey (adult)	0.7
7.	Heifer	0.75
8.	Calf	0.25
9.	Chickens	0.013

Source: Storck *et al.* (1991)

Appendix table 3:Technical efficiency score of the sample households

F.C	TE scores	F.C	TE scores	F.C	TE scores	F.C	TE scores
1	0.781971	39	0.770017	77	0.833162	115	0.860179
2	0.826619	40	0.839805	78	0.755848	116	0.836611
3	0.819246	41	0.765441	79	0.698787	117	0.904246
4	0.836438	42	0.793677	80	0.798700	118	0.857379
5	0.803801	43	0.852013	81	0.647976	119	0.852463
6	0.739058	44	0.780353	82	0.782623	120	0.945824
7	0.846004	45	0.770622	83	0.840594	121	0.618270
8	0.754357	46	0.763195	84	0.877697	122	0.407105
9	0.796228	47	0.703508	85	0.786707	123	0.859316
10	0.830080	48	0.739643	86	0.801864	124	0.811162
11	0.769729	49	0.840777	87	0.831753	125	0.787548
12	0.793258	50	0.801261	88	0.822908	126	0.713776
13	0.813486	51	0.821967	89	0.825066	127	0.847946
14	0.785785	52	0.809089	90	0.859692	128	0.865449
15	0.781792	53	0.807981	91	0.652823	129	0.805637
16	0.796654	54	0.815390	92	0.737804	130	0.575517
17	0.681585	55	0.693151	93	0.853756	131	0.745503
18	0.696021	56	0.783996	94	0.843160	132	0.812561
19	0.824007	57	0.726397	95	0.777134	133	0.689969
20	0.859444	58	0.768681	96	0.821352	134	0.875759
21	0.765801	59	0.774645	97	0.621351	135	0.815154
22	0.748203	60	0.860849	98	0.778888	136	0.791701
23	0.838785	61	0.720587	99	0.792104	137	0.694906
24	0.813119	62	0.454565	100	0.736110	138	0.689735
25	0.835154	63	0.578712	101	0.666144	139	0.743521
26	0.829532	64	0.933127	102	0.783360	140	0.802831
27	0.763478	65	0.817968	103	0.804151	141	0.814506
28	0.844224	66	0.790630	104	0.896363	142	0.846471
29	0.812515	67	0.833330	105	0.845827	143	0.917602
30	0.706176	68	0.787782	106	0.877832	144	0.588620
31	0.879331	69	0.875063	107	0.823619	145	0.732183
32	0.825746	70	0.861688	108	0.728962	146	0.796775
33	0.882081	71	0.785448	109	0.915428	147	0.932719
34	0.708567	72	0.862256	110	0.896451	148	0.631427
35	0.738016	73	0.794859	111	0.822234	149	0.289678
36	0.854246	74	0.569521	112	0.787132	150	0.898001
37	0.712356	75	0.846173	113	0.830976	151	0.852356
38	0.832908	76	0.789925	114	0.867366	152	0.593021

Appendix table 4: Allocative efficiency score of the sample households

F.C	AE scores	F.C	AE scores	F.C	AE scores	F.C	AE scores
1	0.852625	39	0.713004	77	0.954086	115	0.650658
2	0.706534	40	0.812569	78	0.714294	116	0.886799
3	0.756999	41	0.950074	79	0.934854	117	0.623465
4	0.664681	42	0.851181	80	0.727591	118	0.642916
5	0.745758	43	0.659653	81	0.860956	119	0.666996
6	0.943865	44	0.893600	82	0.941891	120	0.916423
7	0.762332	45	0.757398	83	0.790029	121	0.900114
8	0.891776	46	0.967393	84	0.781673	122	0.618672
9	0.941053	47	0.728368	85	0.850764	123	0.693117
10	0.896356	48	0.906836	86	0.912505	124	0.742694
11	0.773083	49	0.725884	87	0.733058	125	0.696631
12	0.838333	50	0.689454	88	0.877012	126	0.807753
13	0.938412	51	0.892122	89	0.757216	127	0.805842
14	0.800143	52	0.832909	90	0.764000	128	0.786413
15	0.913557	53	0.960198	91	0.964304	129	0.811088
16	0.947065	54	0.943999	92	0.887668	130	0.943889
17	0.934416	55	0.883707	93	0.654887	131	0.959458
18	0.887871	56	0.697561	94	0.691756	132	0.885975
19	0.776916	57	0.724880	95	0.721770	133	0.803255
20	0.840727	58	0.710708	96	0.698179	134	0.825533
21	0.798349	59	0.858199	97	0.935182	135	0.929281
22	0.897005	60	0.629724	98	0.717305	136	0.826443
23	0.927162	61	0.793116	99	0.658010	137	0.963560
24	0.856049	62	0.580665	100	0.913546	138	0.956853
25	0.749811	63	0.962967	101	0.848401	139	0.774609
26	0.910340	64	0.976757	102	0.797028	140	0.727564
27	0.880389	65	0.687947	103	0.960498	141	0.637929
28	0.767028	66	0.761236	104	0.646183	142	0.693887
29	0.935685	67	0.833863	105	0.924210	143	0.966096
30	0.938008	68	0.936522	106	0.623582	144	0.595880
31	0.819074	69	0.883615	107	0.773429	145	0.720265
32	0.846673	70	0.668447	108	0.822071	146	0.857304
33	0.805071	71	0.701763	109	0.588508	147	0.967848
34	0.890026	72	0.757686	110	0.601022	148	0.742694
35	0.925032	73	0.649797	111	0.951049	149	0.343120
36	0.841038	74	0.975990	112	0.780255	150	0.956628
37	0.807872	75	0.876575	113	0.937111	151	0.688802
38	0.689549	76	0.795063	114	0.744813	152	0.915171

Appendix table 5: Economic efficiency score of the sample households

F.C	EE scores	F.C	EE scores	F.C	EE scores	F.C	EE scores
1	0.666727	39	0.549025	77	0.794908	115	0.559682
2	0.584034	40	0.682400	78	0.539898	116	0.741905
3	0.620168	41	0.727226	79	0.653263	117	0.563766
4	0.555964	42	0.675562	80	0.581127	118	0.551222
5	0.599440	43	0.562033	81	0.557879	119	0.568589
6	0.697571	44	0.697323	82	0.737146	120	0.866775
7	0.644936	45	0.583668	83	0.664094	121	0.556514
8	0.672718	46	0.738309	84	0.686072	122	0.251865
9	0.749292	47	0.512413	85	0.669302	123	0.595606
10	0.744047	48	0.670735	86	0.731704	124	0.602446
11	0.595065	49	0.610307	87	0.609723	125	0.548630
12	0.665014	50	0.552432	88	0.721700	126	0.576555
13	0.763385	51	0.733295	89	0.624753	127	0.683311
14	0.628740	52	0.673897	90	0.656805	128	0.680600
15	0.714211	53	0.775822	91	0.629520	129	0.653443
16	0.754483	54	0.769727	92	0.654925	130	0.543224
17	0.636884	55	0.612542	93	0.559114	131	0.715279
18	0.617977	56	0.546884	94	0.583261	132	0.719909
19	0.640184	57	0.526551	95	0.560912	133	0.554221
20	0.722558	58	0.546307	96	0.573450	134	0.722967
21	0.611377	59	0.664799	97	0.581076	135	0.757508
22	0.671142	60	0.542097	98	0.558700	136	0.654295
23	0.777690	61	0.571509	99	0.521212	137	0.669584
24	0.696069	62	0.263950	100	0.672470	138	0.659975
25	0.626208	63	0.557280	101	0.565157	139	0.575938
26	0.755156	64	0.911439	102	0.624360	140	0.584111
27	0.672158	65	0.562719	103	0.772385	141	0.519596
28	0.647543	66	0.601856	104	0.579215	142	0.587355
29	0.760259	67	0.694883	105	0.781721	143	0.886491
30	0.662399	68	0.737775	106	0.547400	144	0.350747
31	0.720237	69	0.773219	107	0.637010	145	0.527366
32	0.699136	70	0.575992	108	0.599259	146	0.683078
33	0.710137	71	0.551198	109	0.538737	147	0.902730
34	0.630643	72	0.653319	110	0.538786	148	0.468957
35	0.682689	73	0.516497	111	0.781985	149	0.099394
36	0.718453	74	0.555847	112	0.614164	150	0.859052
37	0.575492	75	0.741734	113	0.778717	151	0.587104
38	0.574330	76	0.628040	114	0.646026	152	0.542716

QUESTIONNAIRE

Questionnaire used for assessing the economic efficiency of smallholder farmers in wheat production: the case of Abuna Gindebarat district, Oromia national regional state, Ethiopia

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

Name of Enumerator ______ Date of interview------ Identification number --- Kebele………

Section I . General information of the Household Head

A. General information

1.1. Name of the household head: ----------------------------------

1.2. Sex of the household head 1.Male 0. female

1.3. Age of the household head : …………… years

1.4. Marital status: 1. Single 2. Married 3. Divorced 4. Widowed
5. Others specify -------------------------

1.5. Religion:1. Muslim 2. Orthodox 3. Catholic 4. Protestant 5.Other specify______

1.6. Educational status of the household head in formal school--------------------------years

1.7. Years of experience in farming -----------------

1.8. For how many years did you cultivate wheat? ----------------------years

1.9. Family size? Male …………… Female…………… Total………………..

1.10. Household family composition in Age, Educational status and Sex.

No.	Name of the family member	Sex 1= male 2= female	Age (years)	Education level in years of	Engagement Full time farmer=1 Part time farmer=2 Full time student =3 Part time	Marital status married =1 Unmarried
1						
2						
3						
4						
5						

Section II. Input Information

1. Total area of land ……… (ha) Cultivated land……… (ha) wheat land .... (ha) Grazing land………(ha) Homestead land………(ha)Other land, specify ……… (ha)

2. What is your major reason to produce wheat? 1. High yield 2. Requires lower labor 3.High grain price 4. Stover (residue) yield5.Pest and disease tolerance 6.No other alternative 7. Other, (specify)...

3. On what farm (land) you planted wheat? 1.owned 2. rented in 3. shared in

3.1. If you rent or shared fill the following table.

Description	Size (ha)	In kind	If in cash how much birr per ha	Proportion (ratio) A*
Share in		--------------	--------------	
Share out		-------------	--------------	
Rent in				------------

Rent out				-------------

A* 1.Equal 2.half 3.one-third 4.one-fourth 5. other, specify........................

Fertilizer applied, Area allocated and seed used for wheat production in 2009/10 E.C.

4.1. Did you use fertilizer for wheat production in 2009/10 E.C. production year?

1. Yes 2. No

4.1.1. If yes, what type of fertilizer? 1. Organic 2. NPS 3.Urea 4. Both NPS and UREA

5. How much did you pay for mineral fertilizers per kg? 1.NPS-----------------Birr/Kg

2. Urea---------------Birr/Kg

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

6.1 If yes, what are the major problems regarding supply and marketing of inorganic fertilizers?

1. Not supplied timely 2. Shortage of fertilizer supply 3. The price is high, no money to purchase 4. The source is far from home 5. Other, specify............................

7. If you are not using organic fertilizer, why? 1. Its bulky to transport

2. Lack of awareness 3. I don't have animals to prepare it4. Others, specify------------

8.What type of seed you used for wheat production in 2009/10 E.C. production year?

1. Local 2. Improved 3. Both types of seed

9. What is the source of wheat seed you used for 2009/10 E.C. production year?

1. Own 2. bought

9.1. If you bought, how much kilogram?----------------------

9.2. If you bought, how much money in cash you paid per kilogram?--------------------

10. Fill in the following table for wheat production in 2009/10 E.C. production year.

Plot	Size of land (Ha)	Slope of the plot A*	Wheat seed used (Kg)		Mineral fertilizers	
			Local seed	Improved	NPS (Kg)	Urea (Kg)
1						
2						
3						

A*1.Meda(flat/plain) **2.**slanty**3.**Hallayya (steep) (please use local language to ask)

13. According to your perception what is the fertility status of the land that you planted wheat?

1. Fertile 2. infertile

14. On average, how many times you plow your wheat land? -----------------------(in number)

15. On average how many minutes do your wheat land takes you to reach it? -------------(in minutes)

16. Number of plots owned? ------------------------------(in number)

<u>Amount of human and oxen labor allocated in the process of wheat production.</u>

<u>Oxen power</u>

1. Did you use oxen for plowing of wheat farm lands? 1.Yes 2. No

1.1. If yes, fill in the following table

Activities	Number of pair of oxen used	Total days	Source of oxen power **A***	If hired			
				How many ox	Total payment in cash (Birr)	Total payment in kind- in the form of crops	
						Crops **B***	Amount in Kg
Plowing							
Threshing							

* Could be more than one. If more than one, please separate using /

A*1.Own 2.Hired 3.Exchange 4. Other (Specify)

B*1.wheat **2.**Teff **3.**Sorghum **4.**Barley **5.**Maize **6.** Bean **7.**Peas

1. During 2009/10 E.C. production yea 88 many household members worked on wheat farm on the following activities?

Activities	How many hh members age b/n **(11-13)**		How many days did they work		How many hh members age b/n**14-16**		How many days did they work		How many hh members age b/n **17-50**		How many days did they work		How many hh members age **> 50**		How many days did they work	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1st Plowing																
2nd plowing																
3rd plowing																
4th plowing																
5th plowing																
6th plowing																
Sowing																
Fertilizer application																
1st weeding																
2nd weeding																
Chemical application																
Harvesting																
Threshing																
Transportation																

2. During 2009/10 E.C. production year did you hired labor for wheat production?

1.Yes **2.**No

2.1. If yes, fill in the following table

Number of workers hired in age b/n **(11-13)**	How many days did they work	Number of workers hired in age b/n **14-16**	How many days did they work	Number of workers hired in age b/n **17-50**	How many days did they work	Number of workers hired in age **> 50**	How many days did they work	Total payment in cash	Total payment in kind-in the form of crops

Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female		Crop **A***	Amount in Kg

* Could be more than one. If more than one, please separate using **/**

A*1.wheat **2.**Teff **3.**Sorghum **4.**Barley **5.**Maize **6.** Bean **7.**Peas

3. Du ... aring /work party (debbo, wonfel, Jiggi ….etc) for your farm? 1. Yes 2. No

3.2. If YES, how many times did you organize a work party on your farm during 2009/10 E.C.production year: __________

3.3. If YES, could you give details for every work party that was organized during 2009/10 E.C. production year?

Number of workers participated in the work party age b/n **(11-13)**		How many days did they work		Number of workers participated in the work party age b/n **14-16**		How many days did they work		Number of workers participated in the work party age b/n **17-50**		How many days did they work		Number of workers participated in the work party age **> 50**		How many days did they work		Crops the work party worked on **B***	Type of work party **C***
Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female		

* Could be more than one. If more than one, please separate using /

B*1.wheat**2.**Teff **3.**Sorghum **4.**Barley**5.**Maize**6.**Bean **7.**Peas**8**. Others specify

C* 1.Wonfel **2.**Debo **3.**Jiggi **4.** Others specify -------------------

4. Is weeding wheat crop a common practice? 1. Yes 2. No

4.1. If yes, how many times do you weed? ---------------------times.

5. What method do you use for weeding?

1. Hand weeding 2. Hoeing 3. I use chemicals 4. Others, specify------

6. Was there insect and pest incidence on your wheat farm in the year 2009/10 E.C. production season? A. Yes B. No

6.1. If yes, did you apply any chemicals for control? A. Yes B. No

7. What was the total cost of chemicals used for production of wheat in 2009/10 E.C.? Fill in the table given below.

No.	Name of chemicals	Unit	Amount	Unit price	Total price
1	Herbicides				
2	Pesticides				

3	Insecticides				

Section III. <u>Crop production</u>

1. In this production year (2009/10) how many quintals of wheat you produced? ----------------(in quintal)

2. Could you please list all the crops that you produced during 2009/10 E.C. and give details?

Crops produced	Area cultivated in Ha	Total crop output in quintal	Total quantity sold in quintal	Price(Birr) per quintal	Total revenue in birr
Wheat					

2. What is the selling price of one quintal of wheat at harvesting time in 2009/10 E.C.production year? ------------------------------ Birr/qt

3. What is the selling price of one quintal of wheat during the slack period of 2009/10 E.C.production year?------------------------Birr/qt.

Section IV. Off/non-farm activitiesand Livestock Holding

<u>Off/non -farm activities</u>

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

1.1. If yes, from which activities do you obtain?

1. Pension payments
2. handcraft
3. Rent from asset
4. petty trade
5. Selling of livestock and livestock products
6. selling of local drink
7. Salary/wage
8. Other (specify) ________________

1.2. If you have other source of income, how much total income did you get in 2009/10 E.C. production year?................Birr

1.3. If you are engaged in off/non-farm activities, how many days per week, on average, do you spend in performing those activities? -----------------------------------

2. Are there any family member who are engaged in off/non-farm activity (If they are contributing to family expenses)? 1. Yes 2. No

2.1. If yes, how many of your family members are engaged in off/non- farm activities? Male -------------------- Female ------------------------

<u>Livestock holding</u>

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

2. If yes, type of animal owned by household

No.	Type of Animal owned	Number owned
1	Oxen	
2	Sheep (young)	
3	Sheep (adult)	

4	Goats (young)	
5	Goats (adult)	
6	Horse	
7	Donkey (young)	
8	Donkey (adult)	
9	Heifer	
10	Cow	
11	Bull	
12	Mule	
13	Calves	
14	Chickens	

Section V. Extension and Credit Services

Extension services

1. Do you have contact with extension workers? 1. Yes 2.No

1.1. If yes, how many days did you visit the extension agent (starting from land preparation until harvesting of crop in 2009/10 E.C. production year ? ________________________ days.

1.2.If yes, for how many days the development workers visit your farm starting from land preparation until harvesting of crops? ------------------------ days in2009/10 E.C.

1.5.Have you ever received any piece of advises specifically with regard to wheat production?

1. Yes 2. No

1.5.1. If yes, for _______________days in 2009/10 E.C.

Credit services

1.Do you have access to credit? A. Yes B. No

2. Do you use credit for wheat production in 2009/10 E.C.production year?

1. Yes 2. No

2.1. If yes, how much money did you borrow? --------------------- Birr

2.2.If yes, what was the source of credit?

1 .Micro-finance institution 2.Idir 3.Relatives

4. Others (specify)______________________

Infrastructures

1. Distance from home of household to Infrastructure

No	Type of infrastructure	Distance in walking minutes
1	Nearest market	
2	Cooperative office	
3	Farmer training center	
4	Health center	
5	School	

7. Problems of wheat production

7.1. What are the major problems of wheat production? (Put in order of their importance)

1. Weeds
2. Low fertility of the soil
3. Diseases
4. high price of improved seed
5. Shortage of rainfall
6. High price of pesticides
7. Others (specify)-----------------