PRODUCTION EFFICIENCY AND MARKET SUPPLY OF SORGHUM: THE CASE OF SMALLHOLDER FARMERS IN KAFTA-HUMERA DISTRICT OF TIGRAY, ETHIOPIA

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PRODUCTION EFFICIENCY AND MARKET SUPPLY OF SORGHUM: THE CASE OF SMALLHOLDER FARMERS IN KAFTA-HUMERA DISTRICT OF TIGRAY, ETHIOPIA

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Postgraduate Program Directorate

We hereby certify that we have read and evaluated this Thesis titled '*Production Efficiency and Market Supply of Sorghum: The Case of Smallholder Farmers in Kafta-Humera District of Tigray, Ethiopia'* prepared under our guidance by Tewoderos Meleaku. We recommended that it be submitted as fulfilling the thesis requirement.

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_____ _____ _____

Chairperson Signature Date

_____ _____ _____

Internal Examiner Signature Date

_____ _____ _____

External Examiner Signature Date

DEDICATION

I dedicate this thesis manuscript to my wife Trhase weldemikale, my mother Aberht Gebrhiwot, and my grandmother Eysus Weldeananiya and Geberhiwot Tefera for nursing me with affection and love and to all my sisters for all their contributions in the success of my life. Additionally those passed away to my father Meleaku kahsay and my brother Yonas Meleaku almighty GOD put their soul in heaven.

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this thesis. Any scholarly matter that is included in the thesis has been given recognition through citation.

This thesis is submitted in partial fulfillment of the requirements for a M.Sc. degree in Agricultural Economics at the Haramaya University. The thesis is deposited in the Haramaya University Library and is made available to borrowers under the rules of the library. I solemnly 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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Date: December 2018

School/Department: Agricultural Economics and Agribusiness

ABBREVIATIONS AND ACRONYMS

AE	Allocative Efficiency
ATA	Agricultural Transformation Agency
CSA	Central Statistical Agency
DEA	Data Envelopment analysis
EE	Economic Efficiency
FAO	Food and Agriculture organization of the United Nations
FGDs	Focused Group Discussions
GDP	Gross Domestic Product
GTP	Growth and Transformation Plan
ILRI	International Livestock Research Institute
KHARD	Kafta-Humera Agricultural and Rural Development
MLE	Maximum Likelihood Estimation
SFA	Stochastic Frontier Analysis
TE	Technical Efficiency
USAID	United States Aid for International Development

BIOGRAPHICAL SKETCH

The author was born in August 1985 from his father Melaku Khsay and his mother Aberht G/hiwot in Dedbit Tabiya, Wukero(Kelt-Awlalo) district of Tigray region. He attended his elementary school at Selam primary school in Wukero and his secondary school and preparatory in Edaga-Hamus. He joined Hawassa University in 2006 and graduated with BSc degree in Agricultural Resource Economics and Management (AREM) in 2008. He was join to Berhan furniture house Mekle city in 2009 and working starting from layman up to professional wood worker for about three years. From November 2013 for about six month he was employed as a teacher in Edaga- hamus high school. Since May 2013 he has been working in Humera Agricultural Research Center, Tigray Agricultural Research Institute as Socio economics Assistant researcher. Currently he is a post graduate student in Haramaya University, college of Agriculture and Environmental Sciences in the program of agricultural economics.

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Production Efficiency and Market Supply of Sorghum: The Case of Smallholder Farmers in Kafta-Humera District of Tigray, Ethiopia

ABSTRACT

Efficiency is an important factor for increasing productivity which leads to increase in market supply to achieve the goal of food security. In economics where resources are scarce and opportunities to use new technologies are limited, increasing efficiency remains the most reasonable means to raise productivity without necessarily developing new technologies or increasing the resource base. Low agricultural production efficiency or inefficiency rises because of failure of market. Failure of market leads to failure of adoption of new technology which is necessary for increasing productivity. So this study aimed to investigate level of production efficiency, factors affecting production inefficiency and market supply of sorghum small holder farmers in Kafta-humera district of Tigray Ethiopia. A multi-stage sampling technique was used to select 289 sample farmers who were interviewed using a semi-structured questionnaire to obtain data pertaining to sorghum production during the year 2016/2017.Stochastic production frontier model was used to identify production efficiency levels, where as Tobit models was used to estimate factors affecting production efficiency levels and supply of sorghum. Accordingly, the mean technical, allocative and economic efficiencies were 78.01 %, 65.21 % and 39.91 % respectively. This implies that output can be increased by 21.99 % or cost can be reduced by 34.79% with the existing level of technology and resources. Input variables such as land, labor, tractor plow power, chemicals, DAP and Urea fertilizers positively affects production of sorghum. The discrepancy ratio (γ) implied that about 91.91% of the variation in sorghum production was attributed to technical inefficiency effects. The likelihood of households to sell their sorghum in the output markets was 67.99%, which is clearly different from the descriptive results. Tobit model revealed that age, education, non-farm income, credit, extension service and training positively and significantly affected technical efficiency while age square and total livestock holding had negatively and significantly affected. Additionally age square, education and frequency of farm visit positively and significantly affected allocative efficiency, while age, non-farm income, credit and extension contact have a negative and significant affect. Economic efficiency was positively and significantly affected by age, education, non-farm income, credit, extension contact and frequencies of farm visit but negatively affected by age square. Quantity of sorghum supplied to the market was positively affected by credit, extension contact, training, sorghum farm size, current price of sorghum and education, while family size and lagged price of sesame negatively affected. These indicate that there is a room to increase in production efficiency and supply of sorghum in the study area. Therefore, government authorities and other concerned bodies should take into consideration the above mentioned demographic, socioeconomic and institutional factors to increase efficiency and supply of sorghum to the market in study area.

Keyword Market supply, production efficiency, Tobit, Stochastic production frontier

1. INTRODUCTION

1.1. Background of the Study

As in many developing countries, agriculture is the foundation of Ethiopia's economy. In the Ethiopian economy, agriculture accounts about 42 percent of the GDP, employs about 85 percent of the labor force and contributes around 90 percent of the total export earnings. The sector is dominated by over 15 million smallholders producing about 95 percent of the national agricultural production. This shows that the overall economy of the country and food security of the majority population depend on small holder agriculture (CSA, 2016). An increase in productivity of agricultural sector is taken as an engine to the increase in the economy of smallholder producers and a driving force to the income equality distribution.

Cereal production and marketing represent the largest sub-sector in the Ethiopian economy, which accounts for about 60% of rural employment (Rashid, 2011). Cereals are the major food crops in Ethiopia which cover 82% of the total land area covered by grain crops and in addition it contributes 87% of the total grain production and provides rural livelihood, food and nutrition security, as well as national income (Taffese *et al*., 2011).

Sorghum is a cereal crop mostly grown in the arid and semi-arid parts of Africa, Asia and Central America which is primarily used in coping food insecurity. Worldwide, sorghum is the fourth most important world cereal crop following wheat, rice, and maize. It is a staple food in the drier part of Africa, china and India. Regarding its production, sorghum is the world's fifth largest crop and Africa's second in terms of tonnage (Ahmed *et al*., 2015).Sorghum is processed in to a wide variety of traditional foods that is still largely a subsistence food crop. Besides, it is important for beverage industries as best alternative to barley (Hager *et al.*, 2014).

Sorghum is one of the major staple crops grown in the poorest and most food insecure regions of Ethiopia. With an annual cereal production of approximately four million tons in 2010, sorghum is the second most important cereal crop produced in Ethiopia, accounting for 19 percent of the total cereal produced in the country and covering about 20 percent of the total area under cereals (FAO, 2013).

Ethiopia is the second largest sorghum producer in Eastern and Southern Africa; next to Sudan. The increment in sorghum production is driven by both land expansion and yield improvement; yield increased from an average of 1.4 tone/ha in 2004/05 to an average of 2.1 tone/ha in 2010/11(increasing by 50 percent); while area under sorghum production increased by 51 percent (from 1.2 million ha in 2004/05 to 1.9 million ha in 2011 (FAO, 2013). The national average sorghum grain yield is around 2.1 tons/ha (CSA, 2014). Sorghum grain is mostly used for local markets in which most of its produces in Ethiopia are consumed at household level. It is the second most important crop for *injera* quality next to *teff*. The grain is also used for preparation of other traditional foods and beverages (ATA, 2015).Despite their relative importance in regional food systems, very little sorghum is supplied to the market processed and has no considerable attention in the national police program.

In western zone of Tigray, sorghoum is mostly produced using the traditional method of farming with low production and productivity. The productivity of it at farm level is found to be too low when compared with the existing research foundation. In western lowlands of Tigray sorghum is the major food crop grown where farmers at the area cultivate sorghum in rotation with sesame and as main food crop. As stated in Bravo-Ureta and Evenson (1994), the fundamental role of efficiency in increasing agricultural output has been widely recognized by the researchers and policy makers. The importance of studying efficiency is that the farmers are not making efficient use of the present technology, then efforts designed to improve efficiency would be less expensive than introducing new technology as a mean of increasing agricultural production output (Grabowski, 1985).Therefore, this study is intended to fill research gap in sorghum production efficiency and factors affecting market supply in the study district.

1.2. Statement of the Problem

The Ethiopian economy is largely dependent on agriculture which is largely a “low-input and low-output” subsistence production system. Despite over 3,000 years of practice by the over whelming majority of the country’s population, agriculture has changed only marginally from its original form. The overwhelming majority of the country’s farmers and herders still rely on age-old technologies and agricultural management practices that invariably result in low productivity and production. This state of affairs has resulted in consistent agricultural

production failures to meet the food and feed needs of a significant proportion of the human and animal population of the country (EPCC, 2015).

Agricultural marketing in Ethiopia suffers from weak market linkages on both the input and output side. Farmers either cannot afford improving inputs or lack the knowledge to use them. Weak systems connection agricultural outputs to processors and numerous barriers exist that prevent quality products from reaching end users, such as insufficient packaging and storing inability of Ethiopian products to meet international market standards and restrictive trade regulations (Mohammed, 2011).

According to previous researches in Ethiopia, there also exists a wide cereal yield gap among the farmers that might be attributed to many factors such as lack of knowledge and information on how to use new crop technologies, poor management, biotic, climate factors and more others (Sisay *et al.,* 2015; Ahmed *et al.,* 2013; Mesay *et al.,* 2013). Should the existing production system is not efficient; introduction of new technology could not bring the expected improvements in the productivity of sorghum and other crops. Given the existing technology, improvements in the production efficiency will enable farmers to produce the maximum possible output from a given level of inputs. Hence, improvements in the level of production efficiency will increase productivity and profit of producers.

The future of sorghum enterprise is linked to the contributions of sorghum to food security, income growth and alleviation of poverty. This is more relevant in developing countries in the Ethiopia continent than in developed nations. Scientific research on improved sorghum varieties and associated technologies has been carried out by many research institutions (FAO, 2013). The government of Tigeray and NGOs has invested a lot of resources in promoting the adoption of these new improved varieties and technologies especially through dissemination of the research work and high yielding sorghum varieties seeds by agricultural extension officers. Despite all these efforts to improve sorghum production there still exists a significant yield gap between the farmers' production levels and the expected yields. According to research conducted by HuARC,201 yield potential for improved varieties for prescribed agronomic conditions ranges between 3.5-4.5 tons per hectare, however farmers are only able to achieve, on average, 1.7 tons per hectare (HuARC,2015).

Farmers particularly, small-scale farmers in western zone of Tigray (the study area) produce sorghum as crop rotation to sesame which is used for home consumption and as source of cash income from selling of the remaining amount. Nonetheless, sorghum production is lower as compared to its potential in the area. Its market price is also lower which could not attract producers to increase on sorghum production. Besides its price, farmers use traditional way of production with lower inputs such as fertilizer, labor force, and poor management practices these all leads to low production efficiency.

Sorghum production and marketing are affected by lack of government attention and inadequate support from research, agricultural programs and rural development policies (FAO, 2013). Sorghum is not as such profitable crop since there is lack of markets demand which can absorb the produce. So, farmers are not encouraged to use inputs that could enhance productivity.

Efficiency is significant factor of productivity, especially in developing agricultural economics where resources are managed and opportunities for development and adopting better technologies are dwindling (Bifarin *et al.*, 2010). Increasing farmers' production efficiency is important to the economic agent and society who have scarce resources (Jema, 2008). There are opportunities to increase output by increasing efficiency. But commercialization in agriculture is also needed which refers to the progressive shift from household production for auto consumption to production for sale in the market. This shift entails that production and input decisions are based on profit maximization, reinforcing vertical linkages between input and output markets (Olwande *et al*., 2015).

Low agricultural production efficiency or inefficiency rises because of failure of markets. Failure of the market leads to failure of adoption of new technology necessary for increasing agricultural output (Mohanty *et al.,* 2015). Low producer prices discourage farmers from using commercial inputs. The ability of input markets (seeds, fertilizer, labour and credit) to respond to increasing demands will require measures that reduce prices paid by farmers for inputs or increase the prices received by farmers for the resulting output. Implementing such measures will strengthen farmers' incentives to adopt the new innovations and research products.

Therefore, since agriculture is a back bone of the nation's food security and economy as a whole, it is important to conduct study which focuses on measuring production efficiency with source of inefficiency and determinant of market supply. As stated in USAID (2009) and Mamo (2009) study on market supply determinants is very vital because the transition of smallholder farmers leads towards commercial production.

1.3. Research Questions

This study attempted to answer the following research questions:

1. What are the existing levels of technical, allocative and economic efficiencies in sorghum production by smallholder producers in the study area?
2. What are the main sources of inefficiencies in sorghum production?
3. What are the determinants of market supply of sorghum at smallholder producers' level?

1.4. Objectives of the Study

The general objective of this study were to evaluate production efficiencies and market supply of sorghum at smallholder farm households level in the study area

Specific objective:

The specific objectives of this study were the following:

1. To measure technical, allocative and economic efficiency levels of smallholder sorghum farmers.
2. To identify determinates of technical, allocative and economic efficiency of smallholder farmers; and
3. To analyze the determinants of sorghum market supply at farm households level.

1.5. Significance of the Study

This study will contribute in smallholder's sorghum production; for its productivity, technical, allocative, economic efficiencies with the sources of inefficiency and factors that determine marketed supply. The result of this study will help sorghum producers in increasing their

output and in market participation. Additionally it is important to researchers for set off point in the related research activities. Farther it is important for development planners, research organizations in designing trainings and technologies which increase production and market which help to ensure food security and to meet the goal of poverty reduction.

1.6. Scope and Limitation of the Study

The study focused on the evaluation of sorghum production efficiency of smallholder producers using stochastic frontier approach and identifying determinants of market supply among farmers by utilizing Tobit model. The scope of this study is limited to the lowlands of Western zone of Tigray, Kafta- Humera district targeting the smallholder sorghum producers. The study will focus on production efficiency, sources of inefficiency and market supply and its determinants.

The findings of the study must be viewed in lights of some of potential limitations. One, the study conducted using cross-sectional data which does not capture inter-temporal differences in production efficiency level and market supply of households in a specific district. Two, the study has also been conducted by taking samples from a district which was selected purposively that could not allow making generalization about the whole region.

2. REVIEW OF LITERATURE

2.1. Concepts and Definitions

2.1.1. Concept of Production Efficiency

Production is the process of transformation of inputs in to output. Production function is purely the technological relationship which expresses the relationship between outputs and different combination of inputs used in the production process (Olayide and Heady, 1982).It shows the maximum amount of output that can be produced with each possible combination of inputs. In agriculture, inputs are usually classified into land, labour, capital, and management. These are usually coordinated by the producing unit whose ultimate objectives or goals may be profit maximization, output maximization, cost minimization, the maximization of satisfaction, or a combination of these motives (Olayide and Heady, 1982).

According to Paul Heyne (2000) efficiency is the relationship between ends and means. Efficiency is one of the most important concepts. There are several meanings of the term - but they generally relate to how well an economy allocates scarce resources to meets the needs and wants of consumers (Tutor2u, 2006).When we call a situation inefficient, we are claiming that we could achieve the desired ends with less means, or that the means employed could produce more of the ends desired. Less and more in this context necessarily refer to less and more value. Thus, economic efficiency is measured not by the relationship between the physical quantities of ends and means, but by the relationship between the value of the ends and the value of the means.

Production efficiency occurs when the maximum number of goods and services are produced with a given amount of inputs at a given period of time with the existing technology. In other words, productive efficiency occurs at the lowest point on the firms average costs curve. This will lies on the production possibility frontier curve on which it is impossible to produce more goods using the existing technology without reducing other goods or service. Thus, productive efficiency is concerned with producing goods and services with the optimal combination of inputs to produce maximum output at the minimum cost. Fully efficient production indicates

the economy is producing on its production possibility frontier. At the production possibility frontier it is impossible to produce more of one good without producing less of another.

Three types of efficiency were identified by different economists. The first analyses of efficiency measures were initiated by Farrell (1957). He distinguished the efficiency measures in to two components, namely technical, allocative. The combination of these measures yields the level of economic efficiency which was given a name of overall efficiency.

According to Farrell (1957) technical efficiency refers to a firm's ability to produce a maximum level of output from a given level of inputs. A technically efficient firm will operate on its frontier production function. Given the stated relationship, the firm is technically efficient if it produces on its outer-bound production function to obtain the maximum possible output which is feasible under the current technology. Putting it differently a firm is considered to be technically efficient if it operate at a point on an isoquant rather than interior to the isoquant (Rahman, 2002).

Allocative efficiency is termed as price efficiency which is the ability of a firm to use inputs in optimal proportions, given their respective prices and available technology. In other way, allocative efficiency is a measure of the degree of success in achieving the best combination of different inputs in producing a specific level of output considering the relative prices of these inputs. Allocative efficiency is achieved when the value consumers place on a good or service (reflected in the price they are willing to pay) equals the cost of the resources used up in production. Condition required is that price equal marginal cost. When this condition is satisfied, total economic welfare is maximized (Tutor2u, 2006).

Economic efficiency is a product of technical and allocative efficiency (Olayide and Heady, 1982). In one sense, the efficiency of a firm is its success in producing as large an amount of output as possible from given sets of inputs. Maximum efficiency of a firm is attained when it becomes impossible to reallocate a given resource combination without decreasing the total output. So that efficiency is ability producing maximum attainable production with exciting technology from limited resources of a production unit of farm to produce a well specified output at the minimum cost

Measurement of efficiency

According to Farrell (1957), efficiency can be measured using either input-oriented or output-oriented approaches. The input-oriented approach addresses the question by how much can input quantities be proportionally reduced without changing the output quantities produced while the output-oriented approach addresses the question by how much can output be increased without increasing the amount of input use that is utilizing the given input more efficiently.

Input oriented measurement

Input-oriented efficiency measure Farrell (1957) illustrates the concept of input-oriented measures of efficiency of a firm that uses two inputs to produce a single output. The assumption of Farrell is that there is constant return to scale. The input oriented approach addresses the question by how much a production unit can proportionately reduce the quantities of input used to produce a given amount of output (Coelli, 1998). As shown in Figure 1 below two inputs X_1 and X_2 are represented on horizontal and vertical axes respectively. The SS' is an isoquant, representing technically efficient combinations of inputs, X_1 and X_2, used in producing output Q. SS' is also known as the best practice production frontier. AA' is an isocost line, which shows all combinations of inputs X_1 and X_2 to be used in such a way that the total cost of inputs is equal at all points. However, any firm intending to maximize profits has to produce at Q', which is a point of tangency and representing the least cost combination of X_1 and X_2 in production of Q. At point Q' the producer is economically efficient.

As in Figure1, observation P utilizes two input factors to produce a single output. SS' is the efficient isoquant estimated with an available technique. Now point Q on the isoquant represents the efficient reference of observation P. The technical efficiency of a production unit operating at P is most commonly measured by the ratio Farrell (1957).

$$TE = OQ/OP$$

Technical efficiency value will take a value between zero and one, and hence an indicator of the degree of technical inefficiency of the production unit. A value of one indicates the firm is

fully technically efficient. For instance, the point Q is technically efficient because it lies on the efficient isoquant. If the input price ratio, represented by the slope of the isocost line, AA' in Figure 1, is also known, allocative efficiency may also be calculated. The allocative efficiency (PQ') of a Production unit operating at P is defined to be the ratio Farrell (1957)

PQ'=OR/OQ

The distance RQ represents the reduction in productions costs that would occur if production were to occur at the allocatively (and technically) efficient point Q' instead of the technically efficient but allocatively inefficient point Q. The total economic efficiency (EE) is defined to be the ratio (Farrell, 1957)

EE=OR/OP

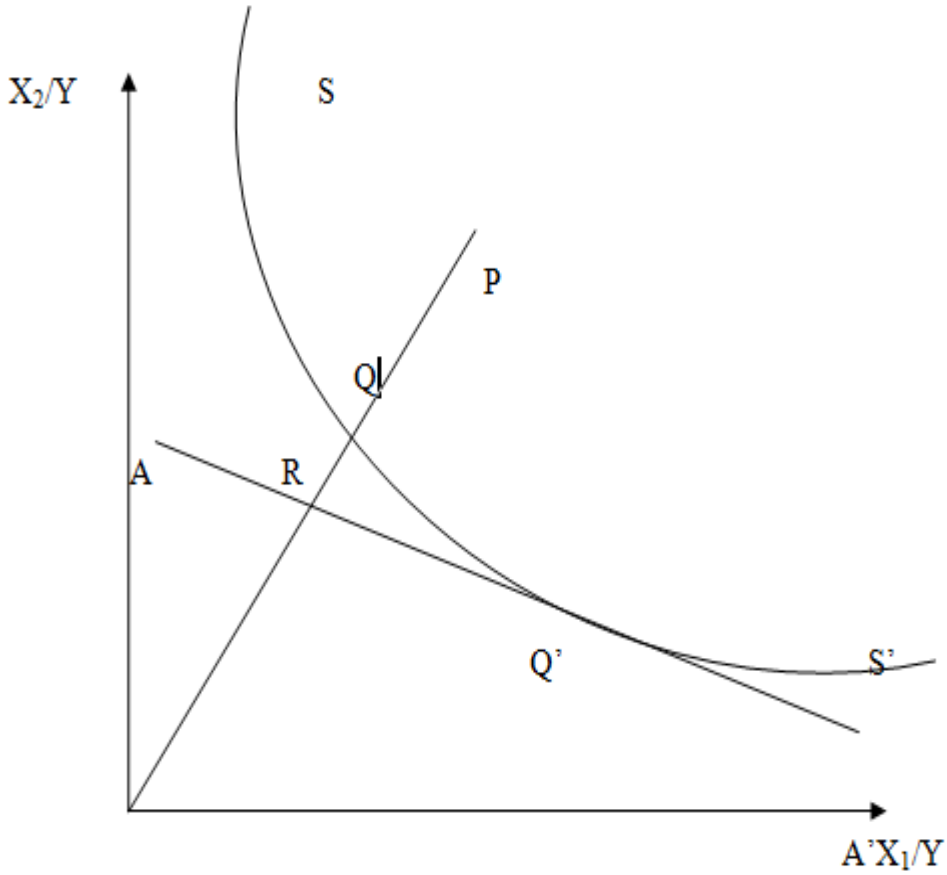

Figure 1.Input oriented measure of technical, allocative efficiencies

Source: Farrell (1957)

The distance RP can also be interpreted in terms of cost reduction. The product of technical efficiency and allocative efficiency measures provides the measure of overall economic efficiency which was termed as overall efficiency by Farrell (1957).

Output oriented measurement

In output-oriented efficiency measures, the question is by how much can output increase without increasing the amount of inputs used or the amount of input is constant. According to Farrell (1957), output oriented measures can be illustrated by considering the case where production involves two outputs (Y_1 and Y_2) and a single input (L). If the input quantity is held fixed at a particular level, the technology can be represented by a production possibility curve in two dimensions as follows AB is production possibility curve (PPC), ED is iso-revenue curve H is the tangency point of PPC and iso-revenue curve that maximizes revenue. PPC shows different combinations of two outputs (Y_1 and Y_2) produced using a given level of input (X_1). A farmer produced on the PPC is technical efficient while it is technically inefficient if it is produced below the PPC or at point Q Alternatively, if all farmers producing along the production possibility curve are 100 percent technically efficient (Coelli *et al*., 2005).

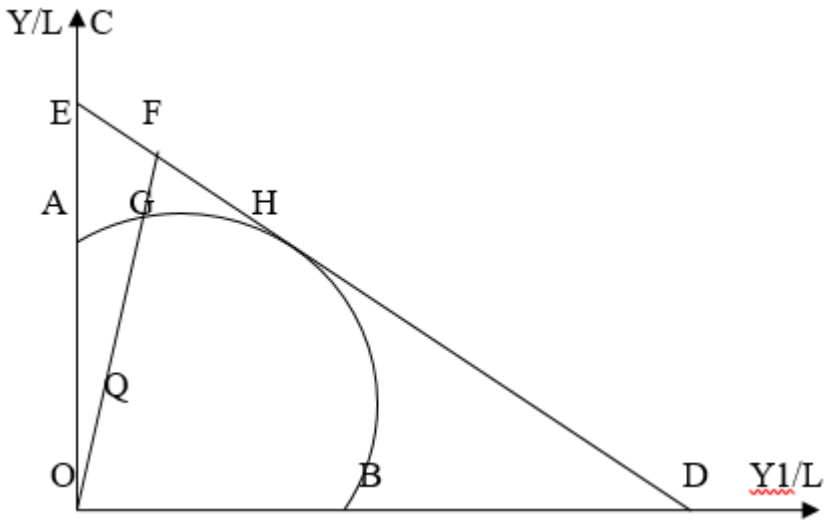

Figure 2.Output oriented measure of technical and allocative efficiencies

Source: (Coelli et al., 1998)

2.1.2. Concept of Market Supply

Market: It is traditionally defined as a specific geographical area where buyers and sellers meet for exchange of goods and services. The most common way we obtain goods and services we do not produce ourselves is to buy them from others who specialize in producing them. To make such purchases, buyers seek out sellers in markets. Markets are ways in which buyers and sellers can conduct transactions resulting in mutual net gains that otherwise would not be possible (Hyman, 1989; cited in Andargachew, 1990). Modern definition considers market as an arena for organizing and facilitating business activities and for answering the basic economic questions (Kohls and Uhl, 1985) described market as how much to produce? What to produce? How to distribute production? A location, a product, a time, a group of consumers, or a level of the marketing system may define it. The choice as to which market definition to use depends on the problem to be analyzed.

Marketing; It is the performance of all business activities involved in the flow of goods and services from the point of initial production until they are in the hands of ultimate Consumer. Marketing-in its simplest form is defined as the process of satisfying human needs by bringing products to people in the proper form, time and place (Branson and Norvell, 1983). The definition of marketing as a process by which individuals and groups obtain what they need and want by creating and exchange products and values with others involves work. Marketing means different things to different people. To the house wife it means shopping food; to the farmer it means the sale of his produce; to the fertilizer distributor it means the selling to the farmer (Abbot and Makeham, 1981)

Agricultural marketing: It is part of marketing that undertakes various activities and involves in moving agricultural outputs from their area of productions to the end users (Kau and Rangi, 1997). In other word it is performance of all activities which direct the flow of goods and services to the consumer from the producers (farmers) in order to accomplish the producer's objectives. Marketing includes packaging, storage, transportation, pricing, financing, risk bearing and even product design. Agricultural marketing involves all those physical, legal and economic services, which are necessary to make products from the farm available to the consumers. Thus creating of form, place, time, and possession utilities is derived from agricultural marketing (Olukosi and Isitor, 1990).

In developing countries, agriculture serves as a major source of income for the population. At macro level, agriculture ensures the food security of the country and is an important channel of foreign exchange earnings, which significantly contribute to the economic growth. Marketing holds its origin from agriculture. It developed only after human beings learned to produce more food needed for them. Few centuries ago, farmers used to consume most of what they produced and rest used to be distributed either as debt obligation or as wages to laborers. However, at later stages, farmers started producing to get required things by way of exchange; which in turn boosted the importance of production. Since everything produced can neither be consumed nor sold so emerged the concept of marketable and marketed Surplus (Sadhu and Singh, 2002).

Marketable and market surplus: Marketable surplus is the quantity of the produce left out after meeting farmer's consumption and utilization requirements for kind payments and other obligations such as gifts, donation, charity, etc. So, marketable surplus shows the quantity left out for sale in the market. The marketed surplus shows the quantity actually sold after accounting for losses and retention by farmers, if any and adding the previous stock left out for sale. Thus, marketed surplus may be equal to marketable surplus, it may be less if the entire marketable surplus is not sold out and the farmers retain some stock and if losses are incurred at the farm or during transit (Thakur *et al*., 1997).

The importance of marketed and marketable surplus has greatly increased owing to the recent changes in agricultural technology as well as social pattern. In order to maintain the balance between demand for and supply of agricultural commodities with rapid increase in demand due to higher growth in population, urbanization, industrialization and overall economic development, accurate knowledge on marketed/marketable surplus is essential in the process of proper planning for the procurement, distribution, export and import of agricultural products (Malik *et al*., 1993).

2.2. Theoretical Framework

Theory of Production Efficiency: In microeconomic theory of production, the producer uses different inputs to produce outputs and in the process desires to maximize profit or revenues. Efficiency can be considered in terms of the optimal combination of inputs to achieve a given

level of output, or the optimal output that could be produced given a set of inputs (Coelli *et al*., 1998). Accordingly, efficiency in major crops production is attained when a farmer uses available farm resources for the purpose of profit or output maximization, given the best production function, level of fixed factors, major crops output and variable factors prices. In this regard, the concept of economic efficiency in the production theory can be used to assess the performance of smallholder crop producers.

The efficiency of a firm is its ability to produce the greatest amount of output possible from a fixed amount of inputs. Another way of putting this is to say that an efficient firm is one that given a state of technical know-how, can produce a given quantity of goods by using the least quantity of inputs possible (Raymond, 1981). According to Fried *et al*. (2008), the measurement of efficiency involves either "comparing observed output to maximum potential output obtainable from the input, or comparing observed input to minimum potential input required producing the output or some combination of the two". A firm or a farm is efficient if and only if there is no more room to increase the level of output decrease the level of input without additional input or reducing output Cooper *et al*. (2006). As Kumbhakar (1994) pointed out that even if different farmer use the same level of input they may produce different output.

Production efficiency represents the efficient resource input mix for any given output that minimizes the cost of producing that level of output or equivalently the combination of inputs that for a given monetary outlay maximizes the level of production (Coelli and Battese, 1996). Small-scale farmers face multiple challenges; this is due to the scarcity of livelihood options outside agriculture. According to Msuya (2008) increasing productivity is crucial for improving the livelihoods of small-scale farmers, who make the majority of the poverty stricken rural population.

Theory of market supply; The origin of decision theory is derived from economics by using the utility function of payoffs. It suggests that decisions be made by computing the utility and probability, the ranges of options, and also lays down strategies for good decisions (Arsham, 2011). This study was base on the theory of utility maximization in producer market participation and channel choice decision. Common theories of smallholder production generally fall under profit and utility maximization and these theories are not mutually

exclusive (Ellis, 1988). Utility is the measure of relative satisfaction that is derived from a good or service (Ahuja, 2005). The decision on whether to participate or not was considered under the general framework of utility or profit maximization (Norris and Batie, 1987; Pryanishnikov and Katrina, 2003). Although utility was not directly observed, the actions of economic agents were observed through the choices they made. Within this framework, economic agents were small-scale ware sorghum producer farmers whose participation decisions were measured by perceived utility or net benefit from any option.

Baumol and Blinder (1991) indicated that while it would seem that firms choose the price and the quantity to be sold, in fact, they choose only one. Once they have selected the price, the quantity they will sell is up to the consumers. Thus, Anderson and Ross (2005) argue that time factor, uncertainties, and other factors pertinent to the decision-maker should be considered. According to Ellis (1988), the theory of profit maximization treats the smallholder farmer as a farm firm, operating in fully formed and competitive input and output markets. Profit maximization predicts a positive response by the farmer to market price changes, i.e. an increase in the real price of output results in higher input use, higher output, and higher net income.

The theory assumes that producers are rational and attempt to choose marketing channels that maximize participation decisions. Market participation decisions have been described as occurring in two steps: 1) whether to participate in the market (buy or sell, versus remain autarkic), and 2) what volume will be bought or sold (Goetz, 1992; Key *et. al.,* 2000; Holloway *et. al.,* 2001; Bellemare and Barrett, 2006). It is assumed that the participation decision is made first and that, conditional on that decision, the household now faces a corresponding quantity decision. The condition characterizing the discrete choice about whether to participate in the market is based on utility maximization.

2.3. Methodological Framework

2.3.1. Models for Efficiency Measurement

The measurement of the performance of firms or farms is often done using the concepts of efficiency and productivity. These concepts have been used interchangeably by different authors and media (Coelli *et al*., 2005; Freid *et al*., 2008; Jema, 2008). But they are not

precisely the same thing. In productivity, the comparison is made between the amounts of output produced to the amount of resources used. In other words productivity is the ratio of output to input. However, efficiency is the ratio of the value of output produced to the cost of inputs used. Efficiency in production or productive efficiency is defined as the degree of success producers achieve in allocating inputs at their disposal and outputs they produce (Zhu *et al.*, 2006).

There are two analytical approaches that can be used to measure efficiency in production: non-parametric and parametric frontier approaches. A parametric approach is represented by stochastic frontier, while Data Envelopment Analysis (DEA) for non-parametric approach. There are strengths and weaknesses to each approach, which may influence the choice of approaches

Non-parametric (DEA) approach: Non-parametric analysis according to Charnes *et al*. (1978) does not require the specification of any particular functional form to describe the efficient frontier or envelopment surface. The principal and most commonly used model in the analysis of efficiency is data envelopment analysis (DEA). DEA can easily handle multiple input and output. Moreover, in DEA, application inputs and output can have very different units of measurement without requiring any a priori trade-off or any input and output prices (Coelli *et al.*, 1998).

DEA is an evaluation method particularly adopted to comprise a set of multiple indicators into overall performance. It enables frontier estimation with the use of non-parametric programming model leading to a ranking of all unit observations based on efficiency scores. The focus is not on the estimation of an average technology production function used by all units analyzed, but to identify the best practicing units. It is based on the notion an organization that employs less input than another to produce the same amount of output can be considered as more efficient. The efficiency frontier is constructed by linear segment that join up those observations with the highest ratio of output to input (Coelli *et al*., 2005).

The model assumes all the deviation from the frontier is the result of inefficiency ignoring the possibility of the effect firms' performance by other factors outside their control. Generally the deterministic frontiers sum-up the exogenous factors to-gather with measurement error or

inefficiency (Forsund *et al*., 1980). The SFA approach is usually preferred to estimate efficiencies of production systems, this is mainly there is deviation because of the nature of agricultural productions depends on climatic conditions and it is affected by measurement errors that attribute for statistical noise in data sets and stochastic frontier models allows decomposition of error terms between statistical noises and inefficiencies measure that enables statistical tests on the validity of model specification (Fekadu, 2004; Abba, 2012).

The main advantages of DEA approach includes it can handle multiple input and output, does not impose any assumptions about functional form, does not take it in to account random error and the distributional assumption of the inefficiency terms. However, DEA is deterministic and all the deviations from the frontier are due to inefficiency, it is sensitive to measurement error and other noise in the data. In addition, it lacks the statistical procedure for hypothesis testing (Coelli, 1995).

The main criticism of DEA is that it assumes all deviations from the frontier are due to inefficiency and because of this, non-parametric frontier methodology may overstate inefficiencies and hence outliers may have profound effect on the magnitude of inefficiency (Llewelyn and Williams, 1996; Forsund *et al*., 1980; Battese and Coelli, 1993 and Fekadu, 2004). In addition, in DEA no account is taken of the possible influence of measurement errors and other noise upon the frontier. All deviations from the frontier are assumed to be the result of inefficiency

Parametric approach: The parametric approaches try to estimate the efficiency scores by estimating an efficient frontier. Thus, the difference between parametric and non-parametric approach is that while nonparametric approaches try to calculate the efficiency scores directly without estimating any frontier, the parametric model estimates the efficient frontier by estimating the parameters of frontier, and then measures the distance of observed input-output data to the estimated frontier. The parametric approach is based on econometric estimation of parameters of the production function whose functional form is specified in advance. It is classified into deterministic and stochastic models. Deterministic models envelope all the observations, identifying the distance between the observed production and the maximum production, defined by the frontier and the available technology, as technical inefficiency. On

the other hand, stochastic approaches permit one to distinguish between technical efficiency and statistical noise.

Deterministic model: The deterministic model assumes that any deviation from the frontier is due to inefficiency. Aigner and Chu (1968) were the first researchers to estimate a deterministic frontier production function using Cobb-Douglas production function. They argued that, within a given farm, firms might differ from each other in their production processes, due to certain technical parameters in the farm, due to differences in scales of operation or due to organizational structures. The deterministic production frontier model can be written as:

$$ln(y_i) = f(x_i; \beta_i) - \mu_i \qquad 2.1$$

Where

i - is the number of farmers

$ln(y_i)$ - is the natural legalism of output of farmer

X_i– is a vector of input quantities used by i^{th} sample farmers

β_i- is a vector of unknown parameter to be estimated

f( ) – is Cobb-Douglas production function

μ_i - is a non- negative random variable associated with technical inefficiency

The technical efficiency of the farmer is indicated by the factor by which the actual (observed) production deviates from the frontier (potential) output. That is, from equation above the technical efficiency (TE_i) of the i^{th} firm is defined as:

$$TE_i = \frac{expY_i}{exp(X_i; \beta_i)} = \frac{\exp(X_i; \beta) - \mu_i)}{exp(X_i; \beta)} = exp(-\mu_i) \qquad 2.2$$

The main criticism of the deterministic frontier model is does not account for the possible influences of measurement errors and other noises upon the frontier (Coelli *et al*., 1998).

Stochastic frontier analysis (SFA)

Stochastic Frontier Analysis (SFA): The development of measuring production efficiency has been the theoretical framework about production efficiency beginning in the decade of 1950 by Koopmans (1951), Debreu (1951) and Shephard (1953) cited in Farrell (1957) and he was the first measuring production efficiency empirically. Letter on SFA was developed independently by Aigner *et al*. (1977) considers both an inefficiency component and a random error. The stochastic frontier allows for deviations from the frontier to represent both inefficiency and an inevitable statistic noise which intends to be a closer approach to reality given that observations normally involve a random walk.

The stochastic frontier approach specifies the relationship between output and input levels using two error terms. One error term is the traditional normal error term in which the mean is zero and the variance is constant. The other error term represents technical inefficiency and may be expressed as a half-normal, truncated normal, exponential, or two-parameter gamma distribution. Technical efficiency is subsequently estimated via maximum likelihood of the production function subject to the two error terms Aigner *et al*. (1977)

Battese and Coelli (1995) explains stochastic frontier production as follows: The stochastic frontier production function postulates the existence of technical inefficiencies of production of firms involved in producing a particular output. For a given combination of input levels, it is assumed that the realized production of a firm is bounded above by the sum of a parametric function of known inputs, involving unknown parameters, and a random error, associated with measurement error of the level of production or other factors, such as the effects of weather, strikes, damaged product, etc. The greater the amount by which the realized production falls short of this stochastic frontier production, the greater the level of technical inefficiency". Given a Cobb-Douglas form of stochastic frontier production function expressed

$$lny_i = \beta_0 + ln \sum_{i=1}^{k} \beta_j \, x_{ij} + \varepsilon_i \qquad 2.3$$

$$\varepsilon_i = v_i - u_i \qquad 2.4$$

Where $\ln(q_i)$ is the logarithm of output of the i^{th} farm household, β_i is a(k x 1) vector of unknown parameters to be estimated, X_i is a(k x 1) vector of inputs used in the production of the i^{th} output, V_i is a random error measuring statistical noise and U_i is a non-negative error term measuring inefficiency effects, the translog Cobb-Douglas production function was chosen due to its flexibility and it's no restriction in returns-to-scale parameters.

Empirical model: the Cobb-Douglas function was adopted in favors of the more commonly used Translog function. The main focus of measures of the technical inefficiencies is on the error term. The study adopts the one-stage estimation procedure proposed by Battese and Coelli (1995) and subsequently by Chirwa (2007) to estimate a stochastic frontier production. The one-stage procedure allows for simultaneous estimation of the parameters of frontier production function with those of the inefficiency model are defined as:

$$\mu_i = \delta_i z_i + \varepsilon_i \qquad 2.5$$

Substitute this into the stochastic production function, the resulting equation is

$$y_i = f(\beta_i; x_i) + v_i - (\delta_i z_i) + \varepsilon_i \qquad 2.6$$

Where x_i is inputs used for the production function and β_i is the coefficient of input variables, z_i is a vector of explanatory variables used in the inefficiency model and δ_i is a vector of unknown parameters to be estimated for the inefficiency variable.

2.3.2. Methods for Analysis Market Supply

Market supply analysis: The aim of the study will be to analysis the sorghum markets supply determinant factors. Ideally, the ordinary least square (OLS) model is applicable when all households participate in the market but in reality not all households participate or at the same level in the markets. Some households may not prefer to participate in a particular market in favor of another, while others may be excluded by market conditions.

Farmer is conditional on the decision to enter into the market, the variables influencing household market participation quantity of sorghum sold or consumed, fact that only a majority of households sell sorghum the minority sorghum producers non-sellers which is zero, in this market is modeled using Tobit or censored regression model. Tobit is as an

extension of the Probit model (Gujarati, 1995); Tobit model was developed by Tobin (1958) for a situation where the dependent variable is censored from above, below, or both. It is indicated that in a situation where the dependent variable is censored.

The Ordinary Least Squares (OLS) is biased if the distribution of dependent variable display practically large number of cases lumped at zero it creates a problem of excluding the nonparticipants from the analysis. This can create problems for standard OLS regression, Such problem is overcome by following a two-stage procedure as suggested by Heckman (1979) or Tobit regression model is recommended (Green 1993). In our case, the dependent variable is the amount of sorghum marketed which involves lower limit censoring at zero for a significant fraction of the observations. Greene (1993) argued that when the dependent variable is censored the conventional regression methods fail to account for the qualitative difference between limit zero observations and non-limit or continuous observations.

The Heckit procedure is a consistent but not an efficient way to control for selectivity bias, while Tobit procedure is efficient and consistent. Technically, if Heck it specification was run using Maximum likelihood Estimation (MLE) procedure without lambda, the results would be identical to Tobit-MLE selection models with iterations constrained to one. Probit or Logit models would be adequate techniques for addressing probability questions. Although it is interesting to know factors that influence the level of sales, at the same time, there is a need for a model that is a hybrid between the Logit or Probit and the OLS. The appropriate tool for such is the Tobit model that uses Maximum Likelihood Regression (MLE) estimation (Tobin, 1958, Gujarati, 1995).

A Tobit model answers both of the following questions: What factors influence the probability of selling? This question is answered by Logit and Probit. What factors determine the level or magnitude of sales? This question is not answered by Logit and Probit models, but by OLS. Using this type of econometric model (Tobit) to determine the factors affecting market participation while controlling for other factors is expressed as:

$$y_i^* = \beta' x_i + \varepsilon_i \qquad 2.7$$

where y_i* is a latent variable (unobserved for values smaller than 0 and greater than 1) representing subsistence or fully supply index; x_i is a vector of independent variables, which

includes factors affecting output sold; β is a vector of unknown parameters; and ε_i is a disturbance term assumed to be independently and normally distributed with zero mean and constant variance σ^2; and i = 1, 2,…n (n=the number of observations). Given the observed dependent variable supply index (y_i), the two limit Tobit model can be specified as:

$$y_i = \begin{cases} 0 \text{ if } y^* \leq 0 \\ y^* \text{ if } 0 < y^* < 1 \\ 1 \text{ if } y^* \geq 1 \end{cases} \qquad 2.8$$

The two limit Tobit model will be estimated using maximum likelihood estimation techniques. However, the Tobit coefficients cannot be interpreted directly as estimates of the magnitude of the marginal effects of changes in the explanatory variables on the expected value of the dependent variable. In a Tobit equation, each marginal effect includes both the influence of the explanatory variable on the probability of participation as well as on its intensity. More explicitly, the total (marginal) effect takes into consideration that a change in an explanatory variable will affect simultaneously the number of sample farmers to market their production and the extent of output sold. However, which marginal effects should be reported depends on the purpose of the analysis (Greene, 2003). Thus, in this study, the marginal effect results will be computed to evaluate the significant effects of the independent variables on the extent of the output sold

2.4. Empirical Studies

2.4.1. Studies on Production Efficiency

Hialeselassie (2005) analyzed the technical efficiency of smallholder farmers using Cobb-Douglas functional form in sorghum production of Raya-Azebo district, Southern Tigray of Northern Ethiopia. He found that, TE of the sample farmers ranges from 16 to 97% with the mean TE of about 79%. He also found that off-farm occupation, age, age square, weeding, and extension contact were found to be important determinants of technical efficiency.

Gosa and Jema (2016) analyzed the technical efficiency, allocative and economic efficiency of smallholder farmers using Cobb-Douglas functional form in sorghum production of Habro district, Eastern Ethiopia. They reported that, TE, AE and EE with the mean of about 74%, 44% and 32% sequentially. Additionally also age, experience, land fragmentation sex and

farm size were found to be important determinants of technical efficiency, age education experience, sex were vital determinants of allocative efficiency and also land fragmentation, extinction contact and farm size economic efficiency.

Hassen *et al.* (2012) analyzed efficiency of crop and livestock production and assessing their potential for improvement in north east Ethiopian high land. They used cross sectional data to analyze economic efficiency of mixed crop and livestock production system and identified its determinate factors, AE, TE, and EE of smallholder using parametric approach. According to the results from the model, the mean TE, AE and EE were found 62%, 51% and 29% respectively. Farm sizes, livestock ownership, availability of labour, total household asset and consumption expenditure found to determine production efficiency. Endrias (2012) analyzed determinants of technical efficiency of smallholder farmers and factors causing TE differential. He found that productivity of maize was significantly influenced by the use of labor, fertilizer, and oxen power. The mean TE was found to be 40%. Important factors significantly affecting the technical efficiency were agro-ecology, oxen holding, farm size and use of high yielding maize varieties.

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

Khairo and Battese (2004), examined technical inefficiencies of maize farmers within and outside the new agricultural extension program in the Harari Region of Ethiopia. Stochastic frontier of production functions were estimated for sample maize farmers within and outside the new agricultural extension program to study technical inefficiencies and identified some of the factors contributing for the variation in productivity. The study found that the average

technical efficiencies were 73 percent and factors such as agricultural extension, formal education and off farm income were important factors affecting maize producer farmers' inefficiencies.

Essa (2011) examined economic efficiency of smallholder major crops production in the central highland of Ethiopia using DAE. He found that the mean technical, allocative and economic efficiency of 79%, 57% and 31% respectively. Age, family size, farm experience, walking distance to the market credit access and total own land cultivated found variables which affected technical efficiency of smallholder farmers in addition also family size, farm experience, member ship to association and role of head in the community were important factors for economic efficiency.

Gemeda (2011) examined efficiency of wheat production in the case of small-scale farmers in Gedeb-hasasa district west Arsi zone of Oromia regional state. He was used cross-sectional data in 2009/2010 production year and stochastic Cobb-Douglas frontier functional form to decompose wheat production efficiency into TE AE, and EE estimates. His results indicated that the mean of TE, EE and AE estimates were 89%, 67% and 76%, respectively. According his results also showed that livestock ownership, extension contact and slope were positively related to efficiency. On the other hand, off/non-farm income, proximity, market distance, land size and age were negatively related to efficiency.

2.4.2. Studies on Market Supply

Ashenafi (2010) used Tobit model to identify factors affecting grain volume of sales. He found farm size, non-farm income, oxen, TLU, yield and market information are vital variables that determine the market volume of sale of grain. Adenegan *et al.* (2012) investigated the determinants of market participation of maize farmers in rural Osun State of Nigeria. Tobit model was used to analyses factors affecting market participation while linear regression model was used to analyze the volume of maize offered to the market for sale. He found that quantity of maize produced, age of household head, household size, farming experience, ownership of farming equipment, involvement in nonfarm income, farmer association, means of information and transportation cost were important variables that determine the volume of sale.

Tobit model was employed to identify factors that determine the supply of wheat by smallholder farmers. The model results showed that six explanatory variables significantly affected the volume of wheat marketed by smallholder wheat producers. Family size, access to credit, off- farm income and livestock holding were negatively and significantly affecting market supply of wheat (Hasen, 2016). And also Muhammed (2011) identified factors affecting the marketed surplus of wheat and *teff* by using OLS regressions. He found that wheat market supply was affected by; quantity of wheat produced, extension contact, price of other related crops and teff affected by sex of the household head, quantity of *teff* produced, access to market information and access to extension services

Wolelaw (2005) identified the major factors that affect the supply of rice at Fogera woreda using multiple linear regressions as a model to study the relationship between the determining factors of supply and the market supply of rice. His study revealed that the current price, lagged price, total amount of rice production in the farm, consumption in the household and weather had affected market supply of rice. Hence, difference in the marketing system of these commodities, type of commodities, and location of the study area can result in differences in factors affecting market supply of the commodities. Gezahagn (2010) studied value chain analysis of ground. Similarly; Kindie (2007) identified major factors that affect market supply of sesame in Metema woreda using cross-sectional data. His study revealed that productivity of sesame, number of oxen owned, number of languages spoken by the head of the household, modern inputs used, sesame area, and time of selling of sesame influenced market supply positively.

Rehima (2006) identified key factors affecting market supply of red pepper at Alaba and Siltie districts of SNNPRS using cross-sectional data with both dummy and continuous independent variables. In her study, she employed Tobit model and came up with the finding that distance to market, frequency of contacts with extension agents, quantity of pepper produced and access to market information influenced market supply of pepper positively in the district

3. METHODOLOGY

3.1. Description of the Study Area

This study was conducted in Tigray Regional State Western zone, Kafta-Humera district. Western zone has four districts which are: Setit-Humera (town), Kafta-Humera, Welkayt and Tsegedie. From these districts the study was conducted in the lowland areas of western zone particularly in Kafta-Humera district. Kafta-Humera district is bordered on the South by Tsegedie district, on the West by Sudan, on the North by Eritrea on the East by North Western Zone of Tigray and on the South East by Welkait district.

The study district has 24 kebeles; all the kebles have potential for sorghum and sesame production. The district based on the 2007 national census conducted by the Central Statistical Agency (CSA) of Ethiopia, this woreda has a total population of 115,580, of whom 52.11% are men and 47.89% women. The district covers a total area of 7176.52 square kilometers with 388,880ha cultivated land. A total of 30,617 households of whom 66.76% are men headed and 33.24% women headed were counted in this district, resulting in an average family size of 3.9 persons in a household. The district is an investment area assigned by the government; so that, there are more than 1,293 investors (categorized as; small 20-50 ha, intermediate 51-150 ha, large151- ha and above) (WTZTIo, 2017).

The annual temperature of the district ranges from 22.2 to 42^0C with annual rainfall ranging from 400-650 mm in the months ranging from June to September (Hagos and Fetien, 2011). However, the considerable amount of the rain falls in July and August. The location of Kafta-Humera area is ranging from 570 to760 m.a.s.l (KHARDo, 2013).

In Kafta-Humera district, agriculture is characterized by erratic rain fed nature that contributes to meet food and cash source of the local farmers. The study area comprises mixed farming system where crops are grown for food and cash crops, and livestock are kept for complementary purpose; as a means of security during food shortage and to meet farmer's cash need. The main crops cultivated in the district are sesame, sorghum, cotton and green gram. Also the people in the district keep/rearing special breed called Begait cattle, goat and sheep to the greater share.

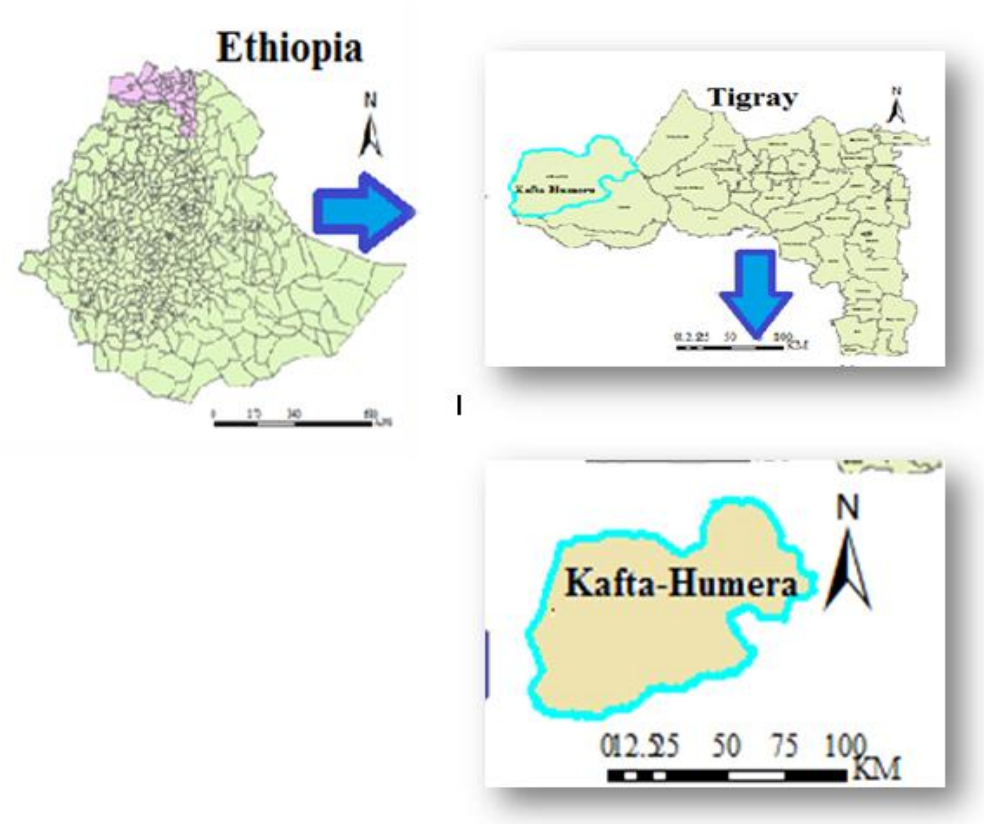

Figure 3.Location of the study area

3.2. Data Types, Sources and Methods of Data Collection

The study was carried out using cross sectional data taking the unit of analysis as smallholder sorghum producers. Both quantitative and qualitative data were collected using primary and secondary data sources. The primary data were collected from sample households of selected kebelles. It was collected using semi-structured questioner and personal interviews. Focus group discussions (FGDs) that involved key informants drawn from small-scale sorghum producers were also used for data collection. Secondary data were collected by reviewing relevant published and unpublished documents.

The data collected from sample households focused on general socio economic characteristics of the individual respondents, production system of respondents, quantity of sorghum produced, quantity of sorghum consumed and supplied to market, frequency of extension visit, market information, credit accessibility and other necessary information were collected.

3.3. Sampling Techniques and Sample Size

Due to the importance of sorghum and its extent of production from western zone of Tigray, Kafta-Humera district was selected purposively. Additionally also taking in to account more or less homogeneity of the population with respect to agro ecology and in its characteristics of production. A two stage random sampling technique was used to select sample households for this study. In the first stage, five kebeles (Maykadra, Baeker, Adebay, Rawyian and Berket) that produce sorghum were selected randomly. In the second stage, the sample farmers were selected using simple random sampling technique from each kebeles proportional to the total number of households of each kebele. The intended total sample size was also determined based on the following formula developed by Yamane (1967).

$$n = \frac{N}{1 + N(e)^2} = \frac{29324}{1 + 29324(0.0586)^2} = 289 \text{ Households} \quad (3.1)$$

Where: n is the sample size needed, N is the total number of smallholder farm households in the study woreda and e is the desired level of precision. Finally, 289 sample households were selected from the woreda and proportional to the size of household population was distributed in to randomly selected kebles. The interviewers, which are presented in the study area, are as following Table 1 below.

Table 1.Kebeles, number of households, and sample size selected from sample Kebeles

Kebele	Number of households	Sample size	Percent
Maykadra	3260	79	27.34
Baeker	2682	65	22.49
Adebay	2229	54	18.69
Rawiyan	1898	46	15.91
Berket	1857	45	15.57
Total	11926	289	100

Source: From KHARDo,(2018)

3.4. Methods of Data Analysis

To address the objectives of this study, both descriptive statistics and econometric models were employed. In descriptive statistics, the simple measures of central tendency, frequency and percentages were used. Where as in the econometric analyses method the stochastic frontier approach (SFA) and a Tobit model were used to estimate the level of technical, allocative and economic efficiencies and the relation between farm level socio-economic, demographic and institutional variables and inefficiencies, respectively. As well as employed to analysis the factors that determine sorghum supply to market.

3.4.1. Measurement of Production Efficiency

Specification of empirical model: The stochastic frontier production function was employed to assess the technical, allocative and economic efficiencies of sorghum producers. In general crop productions are likely to be affected by factors beyond the control of farmers such as climatic conditions, natural hazards, attack of insect pest and diseases. In addition, measurement errors are likely to be high due to difficulties in maintenance of farm records. Hence, choosing a functional form that takes the effect of random terms into account is important. According Aigner *et al*. (1977) and Meeusen and van Den Broeck (1977), the SPF model is specified as follows:

$$lnY_i = \beta_0 + \beta_1 lnx_{1i} + \beta_2 lnx_{2i} + \beta_3 lnx_{3i} + \beta_4 lnx_{4i} + \beta_5 lnx_{5i} + \beta_6 lnx_{6i} + \beta_7 lnx_{7i} + \varepsilon_i \quad 3.2$$

Where Y represent the sorghum output level of ith sample of farmers, the subscript i refer to the number of the i^{th} sample farmer; ln is logarithm to base e; X_1 was labour in terms of man equivalent used in sorghum production; X_2 it was tractor power and measured in hour; X_3 was amount of NPS used in kilogram; X_4 was amount of urea used in kilogram X_5 the amount of pesticide and herbicide chemicals applied in liters; X_6 the amount of seed farmers using during the year; and X_7 cultivated land size that allocated for sorghum production.

Where: $\varepsilon_i = \nu_i - \mu_i$ 3.3

U_i= non-negative random variable, independently and identically distributed as $N(u_i, \delta^2_u)$ which intended to captures the technical inefficiency effects in the production of sorghum measured as the ratio of observed output to maximum feasible output of the i^{th} farm and V_i = a disturbance term independently and identically distributed as N $(0, \delta^2_v)$ which intended to capture events or factors outside the control of the farmers.

Aigner *et al*. (1977) proposed the log likelihood function for the model in equation (3.2) assuming half normal distribution for the technical inefficiency effects (ui). They expressed the likelihood function using λ parameterization, where λ is the ratio of the standard errors of the non-symmetric to symmetric error term (i.e. $\lambda = \sigma_u / \sigma_v$). However, Battese and Corra (1977) proposed that the γ parameterization, where $\gamma = \sigma^2_\mu / \left(\sigma^2_\mu + \sigma^2_v\right)$ to be used instead of λ. The reason is that λ could be any non-negative value while γ ranges from zero to one and better measures the distance between the frontier output and the observed level of output resulting from technical inefficiency. However, there is an association between γ and λ. According to Bravo and Pinheiro (1997) gamma (γ) can be formulated as:

$$\gamma = \lambda^2 / 1 + \lambda^2 \qquad 3.4$$

In SPF hypothesis tests can be made using ML ratio test that are not possible in non-parametric models. A number of tests of hypotheses were made in this study using the usual likelihood ratio (LR) test given by Equation (3.1).

$$LR = -2\{Ln[L(cd) / L(Tl)]\}$$

$$LR = -2\left[Ln(Cd) - Ln(Tl)\right] \qquad 3.5$$

Where: LR = Generalized log-likelihood ratio

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

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

Then this value is compared with the upper 1% point for the χ^2 distribution and decision was made based on that result.

Estimation of the cost /expenditure functions: The cost or expenditure functions for the cost incurred by the sorghum producer for sorghum production were considered by the local market price of each input at its purchasing time. Besides, resources used from own were taken in to considerations, of the market price for all either produced at their farm or formerly bought taking the local market price at that specified time. The permanent working labors will be considered as the permanent hired payment. So that, the total production cost will be obtained by multiplying the per unit input cost for each input by its quantity of input utilized in the production process. In this study the dependent variable is the total amount of expenditure/ cost incurred to produce the sorghum output obtained.

In this study the total cost expenditure were includ land renting cost, cost of sorghum seed, human labor wage, plough power cost, fertilizer cost, chemical cost and plow power cost. Moreover, the cost efficiency of an individual farm defined in terms of the ratio of the observed cost to the corresponding minimum cost given the available technology at that time. Following the adoption of Battese and Coelli (1995) framework for the analysis of data, the explicit Cobb Douglas functional form for sorghum farm in the study area is therefore specified as follows:

$$lnC_i = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + \beta_6 lnX_6 + \beta_7 lnX_7 + (v_i - \mu_i) \quad 3.6$$

Where ln = natural log; C = actual cost of function; X_i = input variable cost; β = coefficient; and (V_i - U_i) = error X_1 it was a labour cost used in sorghum production; X_2 cost of tractor power (plowing cost in hour); X_3 cost of NPS; X_4 cost of urea X_5 is cost of chemicals applied; X_6 cost of seed; and X_7 cost of land allocated for sorghum.

This equation also expressed as:

$$\ln C_i = \alpha_0 + \sum_{i=1}^{n} (\alpha_i \ln w_j + \alpha_j \ln Y^*) \quad 3.7$$

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

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

$$C = C(w_i, y^*; \alpha) \qquad 3.8$$

Where i refers to the i^{th} sample household; C_i is the minimum cost of production; w_i denotes input prices; Yi* refers to farm revenues which is adjusted for noise v_i and α's are parameters to be estimated.

The economically efficient input vector of the i^{th} household X_{ie} is derived by applying Shepard's' lemma as applied in the studies conducted by Alene and Hassan (2006); Ogundari *et al*. (2006); Zalkuwi *et al*. (2010) and Ermiyas (2013) for the expenditure equation and substituting the firms input prices and adjusted output level.

$$\frac{\partial C_i}{\partial w_i} = X_{ie}(w_i, Y^*; \alpha) \qquad 3.9$$

Based on, the optimization profit principle of the Cobb Douglas production function to minimize cost subject to the optimum amount of output to be produced, for optimizing the return the cost must be held at its minimum. Due to the availability of two functions of the cost function and the production function the optimization technique is obtained through the lagrangian method. The minimum cost is derived analytically from the production function, using the methodology used in Alene and Hassan (2006). Given input oriented function, the efficient cost function can be specified as follows:

$$\text{Min} \sum_x C = \sum_{j=1}^{7} X_i \, w_i \qquad 3.10$$

Subject to $Y_i^* = \hat{A} \prod X_i^{\hat{\beta}_j}$ 3.11

Where $\hat{A} = \text{Exp}(\hat{\beta}_0)$

The solution for the problem in the above equation is the basis for driving dual cost frontier. Substituting the input demand equations derived using Shepherd`s Lemma (eq. 3.9) and yield

adjusted for stochastic noise (predicted value of yield) in the minimization problem above, the dual cost function can be written as follows:

$$C(Y_i^*, w; \alpha_i) = HY_i^{*\mu} \prod_j W_j^{\alpha j} \qquad 3.12$$

Where; $\alpha_j = \mu\hat{\beta}_i$, $\mu = \left(\sum \hat{\beta}_j^{-1}\right)$ and $H = \frac{1}{\mu}\left(\hat{A} \prod \hat{\beta}^{\beta_j} j\right)^{-\mu}$

From here all the parameters will be determined the minimum (efficient) cost of production. We can define the farm-specific technical efficiency in terms of observed output (Y_i) to the corresponding frontier output (Y*) using the existing technology.

$$TE_i = \frac{Y_i}{Y_i^*} = \sum_i X_{it}, \frac{P_i}{\sum_i X_i}, P_{ip} \qquad 3.13$$

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

$$EE_i = \frac{C^*}{C} = \frac{\sum X_i P_i}{\sum X_i P_i} = \frac{(g(P, y^*\alpha) + \varepsilon)}{(g(P, y^*\alpha) + V_i)} \qquad 3.14$$

Cost efficiency (CEE) takes the values of 1 or higher with 1 defining cost efficient farm. From these two equations the allocative efficiency (AE) can also be derived as the ratio of the EE to the TE

$$AE = \frac{EE}{TE} = \frac{\sum X_i P_i}{\sum X_{it} P_i} \qquad 3.15$$

3.4.2. Determinates of Production Efficiency

The technical, allocative and economic inefficiency estimates were derived from stochastic production frontier regressed using a censored Tobit model on farm-specific explanatory variables that were explaining variation in efficiency across farms. The rationale behind using a Tobit model was that there were bounded natures of efficiency between 0 and 1 (Hussein, 1989; Greene, 1991). That is, the distribution of efficiency is censored above from unity. 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).

Smallholder sorghum producers are assumed to operate under the same policy and institutional environments and face exogenous variables denoted as Z_i In addition, it is also assumed that these conditions determine farmers' decision to choose set of input vector X and produce output vector Y. Accordingly, in the production process a given farmer is considered to be relatively full efficient if it operates along the boundary of the frontier (Y*) which also defines the level of technology in the system. The boundary of the frontier represents a locus of output points constructed by best practice farms. In this case the output of efficient firms (Y_i) to the potential output along the frontier is equal ($Y^* = Y_i$). Relative efficiency measures, computed as the ratio of actual (realized) to the potential (frontier) output level (Y^*/Y_i), of these farms will be unity ($Y^*/Y_i = 1$).

On the other hand, firms which are relatively inefficient compared to the best practice (frontier) operate at points in the interior of frontier and score less than unity ($Y^*/Y_i < 1$). Furthermore, the efficiency scores of the most inefficient farms in the system are found closer to zero ($Y^*/Y_i > 0$). Therefore, while the scores are bounded between zero and unity with the upper limit set at one, the distribution is censored at both tails ($0 < Y^*/Y_i \leq 1$). Thus, following Amemiya, (1985); Coelli *et al*. (2002); Bravo-Ureta *et al*. (2007); Essa *et al*. (2011) and Endrias *et al*. (2013) the study adopts the two-limit Tobit model. The model is estimated as follows:

$$Y_i^{*}{}_{\text{EE,TE,AE}} = \delta_0 + \sum_{j=1}^{n} \delta_j Z_{ij} + \mu_i \qquad 3.16$$

Where Y_i^* is the latent variable representing the efficiency scores, δ_0, δ_1,,,, δ_{12} are parameters to be estimated, and EE, TE and AE are economic, technical and allocative efficiency of the i^{th} farmer, respectively. Z_i is demographic, socio economic and institutional factors that affect efficiency level. And μ_i= an error term that is independently and normally distributed with mean zero and variance δ^2 ($\mu_i \sim IN(0, \delta^2)$). And, farm-specific efficiency scores for the smallholder sorghum producers range between zero and one. Therefore, two-limit Tobit model can be presented as follow

$$Y_i = \begin{cases} 1, & if \quad Y_i^* \geq 1 \\ Y_i^*, & if \quad 0 < Y_i^* < 1 \\ 0, & if \quad Y_i^* \leq 0 \end{cases} \qquad 3.17$$

Where: *i* refers to the i^{th} decision making unit is inefficiency scores of the i^{th} DMU (Decision-Making Units). Y_i^* is the latent inefficiency variable, β_j are parameters to be estimated and μ_i is an error term that is independently and normally distributed with mean zero and common variance of δ^2 ($\mu i \sim NI(0, \delta^2)$). Z_{ij} are host of socio economic, institutional and demographic variables.

3.4.3. Determinants of Market Supply

To adders the market supply determinates of sorghum by smallholder farmers were used Tobit model because some farmers not supply their sorghum grain product to the market. So that Tobit model is an appropriate model to analyze the factors determining the marketed supply of sorghum grain than the linear model.

Statistically Tobit model can be specified as:

$$y_i = \beta_0 + \beta_i x_i + u_i \qquad 3.18$$

$$If \quad RHS > 0$$
$$y_i = 0$$

Where

RHS = right-hand side, additional X variables can be easily added to the model

Yi =Volume of sorghum marketed (dependent variable)

βo = intercept

βi =Coefficients of i^{th} independent variable

x_i = Independent variable

u_i = Unobserved disturbance term or error term

Maddala (1997) proposed the following techniques to decompose the effects of explanatory variables into quantity supply and intensity effects. Thus, a change in explanatory variable has the three effects. In this study, the marginal effect of explanatory variables on the expected value of the sorghum marketed surplus (equation 3.19, the change in intensity of marketed surplus with respect to a change in an explanatory variable (equation 3.21) among sellers were used to estimate marketed surplus of sorghum by smallholders in the study areas and the change in the probability of market participation as independent variable X_i changes (equation 3.21).

The marginal effect of an explanatory variable on the expected value of the dependent variable is:

$$\frac{\partial E(Y_i)}{\partial (X_i)} = F(Z)\beta_i \qquad 3.19$$

Where, F (Z) is the value of the derivative of the normal curve at a given point

Z is the Z score for the area under normal curve, $Z = \frac{\beta_i x_i}{\sigma}$

σ is the standard error

The change in intensity of quantity supplied with respect to a change in an explanatory variable among sellers:

$$\frac{\partial E(Y_i / Y_i^* > 0)}{\partial x_i} = \beta_i \left[1 - Z \frac{f(Z)}{F(Z)} - \left[\frac{f(Z)}{F(Z)} \right]^2 \right] \qquad 3.20$$

Where, F(Z) is the cumulative Normal distribution of Z

β_i is a vector of Tobit maximum likelihood estimates.

The change in the probability of market participation as independent variable X_i changes:

$$\frac{\partial F(z)}{\partial X_i} = f(z)\frac{\beta_i}{\sigma} \qquad 3.21$$

The interpretations of these marginal effects depend on the point of interest based on the focus of the study. For instance, if the interest is to make statements about the conditional mean function in the population despite the censoring, equation 3.19 is used for the censored data. If a researcher is interested on average value of the population of study, and how those values vary with covariates, equation 3.20 is used and finally, if one wants to interpret, for example, about the determinants of average values of the dependent variable among those who have already participated in a program, equation 3.21 is used. However, in literature, all the three marginal effects are interpreted to show the change in the probability of participation, intensity of dependent variable among the whole population and intensity of use among the participants only, respectively.

3.5. Definition of Variables, Measurement Level and Working Hypothesis

Dependent variables

Sorghum output: It is a dependent variable, which is continuous that represents the actual quantity of sorghum grain produced by individual household in 2016/2017 measured in quintal (log-normalized).

Inefficiency score (u_i): It is a dependent variable that represents technical, allocative and economic inefficiencies of sorghum production.

Sorghum market supply: It is the dependent variable which is the quantity of sorghum sold during 2017/18 year measured in quintal. It represents the log of the actual volume of sorghum marketed by farmer.

Inputs

Labour: It is total number of family and hired laborers used in different stages of sorghum production such as land preparation, planting, weeding, harvesting and threshing. It was converted to man equivalent using conversion factors for different labour classes participated in the production process. The man-equivalent was computed by taking into account the age and sex of the laborer and using standard conversion factor reported by reported by Strock *et al*. (1991). The study conducted by Gosa (2016) on economic efficiency of sorghum production for smallholder farmers in eastern Ethiopia the Case of Habro district show that

labour leads to increase production efficiency of the farmer. Similarly the study conducted by Samuel and Sharp (2007) on commercialization *teff* expediters on input affects supply positively. So in this study labor was expected to have positive relation with production efficiency and volume of supply.

Plough hour: It was measured in tractor hour used in the production processes. Both sorghum production efficiency and volume of supply were expected to be affected by tractor hour used by sorghum producing farmers in the study area for cultivation of his/her land. According to Desale (2016), accessibility and amount of tractor hour positively affected production efficiency of sesame. In Kusse (2016), oxen-day affected production efficiency positively. Similarly; in the study conducted by Haileselassie(2005) on sorghum affects in opposite. So in this study amount of plough hour expected to have positive relation with both production efficiency and market supply.

Amount of fertilizer applied: It is a continuous variable measured in kilo grams which refers to the total amount of inorganic fertilizers used in sorghum production which increases the productivity of sorghum. Theoretically the optimal level of fertilizer application boosted the production efficiency of the farmer. The study conducted by Musa (2011) found positive relation with production efficiency. And also according to Beza (2014) amount of fertilizer affected positively the supply of maize. So amount fertilizer applied was expected to positively affect production efficiency and market supply of sorghum.

Amount chemical applied: It is a continuous variable representing the total amount of chemicals used in weeding and diseases and pests controlling measured in liter. It is expected to increases the productivity of sorghum through improving management of pest, disease and weed. The study conducted by Kifle, (2014) found positive relation with production efficiency. In this study it was hypothesized that amount of chemical applied was expected to have positive relation with both production efficiency and market supply.

Amount of seed used: This refers to the amount of seed used in the production of output; it is continuous variable measured in kilogram. Theoretically the optimal amount of seed boosts the production efficiency of the farmer. Therefore, amount seed applied was expected to have positive relation with both production efficiency and market supply.

Land: This represents the total physical unit of land under sorghum in hectare. The land may belong to the farmer; it may be obtained through renting or through share-cropping arrangements in the production season. The study conducted by Schultz (1964) and Awol (2014) suggest that small farms are more production efficient than large farms. Similarly; the study conducted by Gosa (2016) and Hassen (2016) and oppose to this proposition by justifying the existence of positive relationship between farm size and production efficiency based on the economies of scale. As well as the studies conducted by Barnson (1983) and Butler (2005) found expanding the area under crop increased the market supply of the crop. So this study was hypothesized amount land for sorghum production used expected to have positive relation with both production efficiency and market supply.

Cost of land (PLand): It is the annual cost of land that is a payment for tax or rent expressed in Birr/ha for all plots of land used in sorghum production in the study area. The rental value of the land was used for owned land rent paid to same quality and size paid in the locality (opportunity cost of land) will be taken and for rented-in land the amount paid will be taken as its price. In our country, purchasing agricultural land hardly exists but considerable tenancy, rental value of land probably provides a fairly good indication of the net value of cost of land used.

Cost of labour (PLabour): It is the average wage in Birr per day paid for hired labour used in sorghum production process in the study area. For hired labor the wage paid to the workers was used and for family labor (unpaid workers) it will be estimated in terms of opportunity cost of market wages (permanent hired wages) during the production season.

Cost of seed (PSeed): It is the cost of seed in Birr/ha used for sorghum production in the study area during sowing time. The amount paid by farmers to purchased seed was recorded and for owned seed the price required for the same quality and quantity in the local market during the same production season was considered.

Cost of fertilizer (PFrtz): This refers to the payment in Birr/ha for DAP and urea applied by each farmer in sorghum production in the study area.

Cost of plough hour (PTractor): It is the average payment in Birr per hour for tractor used in sorghum production process in the study area.

Cost of chemicals (PChemical): It is the payment for herbicide in Birr/litter used for sorghum production by each household in the study area.

Explanatory variables

Sex of the household head (Sex): It refers to the natural biological differences between men and women. This is a dummy variable that is valued as 1 if the household head is male and 0, otherwise. Due to many socio-cultural values and norms, males have freedom of mobility and participation in different meeting, as result male headed households have more access to resources and information related to superior production technologies, opportunity of gating trainings on the production and practical experiences in farming than female headed households. The study conducted by Mohamed, (2012) found that households headed by male are more efficient than female households in wheat production in Sudan. This study was hypothesized that sex has negative relationship with production inefficiency and positive relationship with market supply.

Number of extension contact (EXCT): This variable was measured as a count variable of the frequency of contacts with extension workers in a year. The contact of farmer with extension service provider, the contact may in the form of trainings, home visits, interpersonal and group discussion or meetings advanced by development agent about sorghum production during the production year which helps in the weeding, pest, insect and diseases managing on sorghum production efficiently to produce the maximum attainable level of output with existing resource. It is measured as number of contact of development agent with smallholder farmers. Farmers who have frequent contact with extension workers will have better information access on improved technology usage; adopt better technology that increases the amount of commodity supplied to the market and improves agricultural production efficiency Muhammed (2011), Bravo-Ureta *et al.* (1994). In counterpart extension visit and assets positively and significantly affect the production inefficiency (Ermiyas, 2013; Musa, 2013). This study hypothesized that extension contact expected to have positive relationship with both production efficiency and supply to market.

Amount of credit Obtained (Credit): It is a continuous variable measured by amount of credit obtained in ETB (log normalized). Credit may systematically affect agricultural

production in either direction. Credit is important source of financing and makes traditional agriculture more productive through purchase agricultural inputs in the production process such as improved seeds, fertilizer, chemical, and labour and farm expansion in time purchase and enables the smallholder farmers to increase sorghum production efficiency and market supply. The study conducted by Okike *et al.* (2001),Kifle *et al*.(2017) and Woldegebrial, (2010), Musa, (2013) reveal that receiving credit contributed to production efficiency positively and also credit have positive relation with market supply Amare, (2015).In the other hand credit, the study conducted by Fantu *et al*. (2015) on cereal productivity and its drivers the case of Ethiopia had found negative effect on technical efficiency of major crops due to miss use of credit on the agricultural production. In this study, credit was expected to have positive relationship with both production efficiency and market supply.

Livestock holding (TLU) (other than oxen): It is continuous variable measured in Tropical Livestock Unit and also used as proxy variable for the wealth status of farmers. Livestock can be a source of income when there is a need of external inputs, a source of draft power and provide manure to improve soil fertility. Farmers who have more livestock size are expected to be more efficient in sorghum production than those who have no or few livestock size; this indicates that livestock and crop production as supplementary enterprise and has negative relationship with production inefficiency (Sisay *et al*. 2015; Solomon, 2014; Asres *et al*., 2014; Pretty *et al*., 2011; Mohammed, 1999; Fekadu, 2004; Aynalem, 2006. However, as indicated in Shumet, 2011; Hassen *et al*., 2015 and Kinde ,2005 livestock production can be competitive for different resources such as land, labor and management and has positive relationship with livestock size and production inefficiency. In addition to this farmer could sell more sorghum when he/she produces more. On the other hand, when the household has less production, it must either borrow money or sell his livestock to meet household needs. Farmers who have low production need to specialize in livestock production. In this study livestock holding size excluding oxen was expected to have positive relationship with production inefficiency and negative with volume of sorghum marketed.

Age of the household head (AgeHH): It is a count variable, which refers to the age of the household head measured in years. It is believed that age can serve as a proxy for experience and reflect the capacity of the farmers who have to engage in farming activities. In this case

farmers with more years of experience are expected to be more efficient. On the other hand, older farmers are relatively unlikely to change their long life farming exercise, which is usually traditional and less efficient. Moreover, labor productivity, farm managerial capacity, innovating new technology and information catch decreases with age; younger farmers tend to be relatively more productive, because of the hard nature of farm operations (Ike and Inoni, 2006).In this study, age was expected to have positive relationship with production inefficiency and negative relationship with market supply.

Off/non -farm activities (OFF-FARM): This variable is measured as a continuous variable, measured in the amount of income from off-farm/non-farm activities earned by farm per annum in ETB (log normalized). Off/non-farm activities refer to activities other than farm and out of his/ her farm respectively. It can supplement the agricultural activities in terms of providing extra cash income to buy necessary agricultural inputs timely and improves risk management of the farmer. On the other hand off/ non-farm activities can compete with agricultural activities in terms of time and labor (Hyuha, 2006). However, in study made by Al-hassan (2012), it was indicated that off/non-farm activities have negative impact on technical efficiency of smallholder paddy farmers in Ghana. In this study participation in off/ nonfarm activities was expected to have negative relationship with production inefficiency and positive relationship with market supply.

Education level of the household head (Education): It refers to the formal schooling of household head during survey period and measured in years of schooling. Farmers are expected to acquire the ability of better management through education and can be used as a proxy variable for managerial ability. Those households' head that had formal education are ready to accept new information, adopt technological innovation that enhances willingness to use the recommended agronomic practices. Exposure to education is expected to increase farmers' ability to use relevant information to collect, retrieve understand, analyze, and interpret the advantage of different technologies more easily than uneducated farmers (Gbigbi, 2011). Education determined production efficiency positively and significantly (Jema, 2006; Al-hassan, 2012; Musa, 2013). In this study, education was expected to have negative effect on production inefficiency and positive effect on market supply.

Farm size other than sorghum (FarmZ): It is a count variable, which is total size of cultivated land other than land covered by sorghum in hectare that a farmer owns for crop production during 2016/17 production year. Studies done by Jema (2006), Kinde (2005), Berhan *et al.* (2014), Sisay *et al.* (2015) and Hassen *et al.* (2015) indicated that as farm size of the farmer increase the managing ability of the farmer decreases, with a given level of technology. Hence, size of farm land was expected to be positively related to production inefficiency. However, a study conducted by Hener, (2014) indicated negative relationship between farm size and production inefficiency. The justification is that large farms use modern agricultural technologies. Therefore, they can be less inefficient due to economics of scale. This study hypothesized farm size other than sorghum is expected to have positive relationship with production inefficiency.

Total cultivated land (CultivZ): This refers to the area of cultivated land (own, shared or rented in) that the household managed during 2016/17production season under sorghum. Farmers with larger area of cultivated land have the capacity to use compatible technologies that could increase the productivity by adopting improved variety than small size farms. According to Bedada *et al*. (2015), large farms were providing large yield than small size farms. Hence, it was hypothesized that cultivated land size to have positive effect on volume of sorghum marketed.

Training (Training): Training is an important tool in building the managerial capacity of the farmers. A farmer who get training on production and marketing of sorghum are more productive than those not received. This is due to increases the awareness of farmers and exposes to new ideas and information about productivity of inputs, opportunities, input and output management. Ismat *et al*. (2009) and Hareg (2012) found training positively related to production efficiencies. Rehima (2006) found that extension contact positively affected the marketed supply of pepper. In this study, training was expected to have negative relationship with production inefficiency and positive with market supply.

Frequency of sorghum farm visit: It is a count variable indicating the number of times the household members visit their sorghum farm. Theoretically, this could negatively contribute to inefficiency because if the farmer visits his farm frequently, he/she is managing his/her farm better. The producers who frequently visit his/her farm could also perform production

activities timely and actively. Therefore, in this study negative relationship between frequency of farm visit and production inefficiency and positive relationship with supply of sorghum to the market was hypothesized.

Family size (FamilyZ): It is measured by the total number of family members in the household. Family size was hypothesized to affect technical efficiency level of the farmers positively. This is because, as labor is the main input in crop production, a farmer that has large family size could carry out the required agronomic practices even in peak production periods. Family size was found positively related with production efficiency (Sisay *et.al*, 2015; Henry, 2014). However, family size was found to relate negatively to production efficiency in studies conducted by Essa (2011) and Fekadu (2004). Additionally the study found by Woldemichael (2008) and Mebrhathom (2014) found, number of households had positive effect on market supply of milk and sale of *teff*. According Astewel (2010), family size influenced sale of rice negatively. In this study family size was expected to have indeterminable relationship with production inefficiency and negative relation with market supply.

Current price of sorghum (CurntPsorg): It is continuous variable representing the farm get price of sorghum measured in ETB per quintal in 2017/2018 year (log normalized). From supply demand price theory holding other thing constant as price increases demand fails and supplies increases from this supply of sorghum was directly and positively related with price of sorghum.

Lagged price of sorghum (lagPsorg): It is the average price of the sorghum product in the previous year measured in ETB per kilo gram of sorghum in 2015/16 year (log normalized). From supply demand price theory hold other thing constant as price of the previous year increases demand fails and supplies increases from this supply of sorghum have directly and positively related with previous price of sorghum.

Lagged price of sesame: It is the average price of the sesame product in the previous year measured in ETB per kilo gram of sesame in 2015/16 year (log normalized). This is because these two crops are the most important crops in terms of area cultivated, use of fertilizer and hired labour, and hence there is severe competition for all resources, including land. Hence, it

was hypothesized that lagged price of sesame has a negative effect on quantity of sorghum supplied to the market.

Summary of production efficiency and supply variables definition, measurements and hypothesis is given as follow

Table 2 Effect of inputs on sorghum production efficiency and supply

Inputs		Type	Measurement	Hypothesized effect
Land		Continuous	Hectare	+
Seed amount		Continuous	Kilogram	+
Labour		Continuous	Man-day	+
Tractor plough		Continuous	Hour	+
Amount of chemical used		Continuous	Litter	+
fertilizer	DAP	Continuous	Kilogram	+
	Urea	Continuous	Kilogram	+

Table 3 Inefficiency and sorghum market supply variables measurement and hypothesis

Explanatory variables	Type	Measurement	Hypothesized effect	
			production efficiency	Market supply
Sex of the household head	Dummy	0 if female, 1 if male	+	+
Frequency of extension contact	Count	Number	+	+
Amount of credit obtained	Continuous	ETB	+	+
Livestock holding	Continuous	TLU	+	-
Farming experience	Count	Years	+	+
Age of household head	Count	Years	-	-
Off /Non-farm activities	Continuous	ETB	+	-
Education level	Count	Grade	+	+
Farm size other than sorghum	Continuous	Hectares	-	
Land cultivated for sorghum	Continuous	Hectares		+
Training	Dummy	0 if no 1if yes	+	+
Family size	Count	Number	+	-
Frequency of farm visit	Count	Number	+	+
Current price of sorghum	Continuous	ETB/kilogram		+
Lagged price of sorghum	Continuous	ETB/kilogram		+
Lagged Price of sesame	Continuous	ETB/kilogram		+

4. RESULTS AND DISCUSSION

This chapter is divided into two main sections: descriptive statistics and econometric results. In the first part, results of descriptive analysis are reported in which, survey data were used to describe the socio-economic characteristics, demographic characteristics, and agricultural activities of the farmers. In the second part, econometric results of overall efficiencies were estimated for sorghum producing farmers. Following this, factors affecting inefficiencies and supply were computed.

4.1. Descriptive Results

The descriptive analysis addresses different statistical measures such as frequency, mean, standard deviation, percentage, minimum and maximum values of variables used in the model.

4.1.1. Production and Marketing of Sorghum in the Study Area

Table 4 Production and marketing of sorghum

Variable	Non participants		Market participants		Both		t-test
	Mean	Std	Mean	Std	Mean	Std	
Sorghum farm size (ha)	1.16	0.47	3.81	1.81	3.38	1.93	-9.95
Production (Qt)	15.06	2.29	76.30	53.38	66.34	53.83	-7.85
Yield(Qt/ha)	14.05	3.59	19.18	6.59	18.35	6.59	-5.19
Sales quantity(Qt)	0	0	58.98	52.08	49.39	52.39	-7.75
Consumption(Qt)	14.65	2.27	16.73	4.29	16.39	4.11	-3.23
Conserved for Seed (Qt)	0.41	0.13	0.59	0.26	0.56	0.25	-4.67

The production of sorghum is the most important source of food and cash crop in the district. Additionally, farmers used as crop rotation with sesame for improving the fertility status of the soil and to break-down the severity of pests and diseases in their farm. The result illustrates that the overall average land allocated for the production of sorghum by sample sorghum respondents was 3.38 hectares with a standard deviation of 1.93. The average land allocated by market participant and non-participant households were 3.81 and 1.16 hectares respectively. The test statistics indicates that the mean difference of sorghum produced between market

participants and non-participants were statistically significant at 1% probability level (Table 4). The average sorghum produced per sample households was different between market participants and non participants with the overall mean produced 66.34 quintals with standard deviation of 53.83. The average sorghum produced by market participants and non-participants were found to be 76.30 and 15.06 quintals respectively. The test statistics revealed that the mean difference of sorghum produced between market participants and non-participants were statistically significant at 1% probability level (Table 4).

In the study district, from the total volume of sorghum produced, on average 49.38 quintal of sorghum was supplied to market by individual households with standard deviation of 52.39. The minimum and maximum amounts of sorghum supplied to the market by sample respondents were zero and 292 quintal, respectively. Additionally the average amount of sorghum consumed by a household and preserved for seed was16.38 and 0.58 quintal respectively. From the sorghum output produced 74.45% was supplied to market and the remaining 24.71% and 0.84% was used for home consumption and preserved for seed respectively (Table 4).

4.1.2. Inputs of Sorghum Production

Table 5 sorghum production inputs

Variables	Non participant		Market participants		Both		t-test
	Mean	Std	Mean	Std	Mean	Std	
Sorghum farm size(ha)	1.16	0.47	3.81	1.81	3.38	1.93	-9.95
Plow power(hour)	0.63	.39	2.21	1.20	1.95	1.26	-8.90
Seed(kg)	11.83	5.43	36.89	1.19	32.82	19.48	-9.16
Herbicides(liter)	1.59	0.92	5.96	3.22	5.26	3.39	-9.23
Labour used	31.74	10.95	95.99	2.81	85.54	46.77	-9.99
NPS(Qt)	0.49	0.24	1.91	1.33	1.68	1.33	-7.34
Urea(Qt)	0.26	0.12	0.98	0.66	0.87	0.66	-7.49

The production function for this study was estimated using seven input variables. On average farmers land allocated for sorghum production by sample households during the survey period,

ranged from 1 to 12 ha with an average of 3.375 ha. The average amount of seed sample households used was 32.817Kg. Additionally human and plow power input are also vital in the farming system in the study area. Sample households, on average used 85.543 man equivalent labors and 1.949 tractor hours for the production of sorghum during 2017 production season. In the study area farmers use NPS and urea for sorghum production. Hence, on average farmers used 1.68 Kg of NPS and 0.865Kg of urea. The analysis of herbicide application shows that the mean value was 5.26 liter with standard deviation of 3.38liter (Table 5). The t-test result showed significant difference between groups of households at 1 % level of significance. Similar to the production function, the mean and standard deviation of each of the variables used in the cost function are depicted in table 6.

4.1.3. Production Input Cost Function

Table 6 Input costs and total cost of production in Birr

Variables	Non participants		Market participants		Both		t-test
	Mean	Std	Mean	Std	Mean	Std	
Total cost	7443.03	2085.54	27501.6	15188.85	24223.21	15788.56	-9.07
Total cost per ha	6482.48	526.55	7091.42	1080.24	6992.39	1035.10	-3.77
Cost of production	497.25	151.81	399.31	99.01	415.24	114.86	5.63
Total land cost	776.40	332.68	2557.62	1249.91	2267.94	1326.10	-9.69
Plow power cost	417.46	274.34	1479.91	813.50	1307.12	848.56	-8.85
Total seed cost	96.07	49.84	306.47	157.41	272.26	164.87	-9.06
Total chemical cost	160.65	103.99	693.59	426.13	606.92	438.74	-8.51
Total labour cost	3524.28	1625.45	11767.11	5920.29	10426.58	6247.94	-9.46
Total NPS cost	614.61	302.27	2415.47	1670.08	2122.6	1670.86	-7.36
Total urea cost	301.89	135.85	1139.40	760.14	1003.19	763.10	-7.52

On average, the total cost of 24223.21 Birr was required to produce 66.34 quintals of sorghum. Among the various factors of production, the cost of human labor accounted for the highest share (10426.58 Birr). Following the cost of labor, cost of land renting takes major share out of total cost of production which is 2267.94 Birr. Among other inputs, cost of seed takes the smallest (272.26 Birr) share out of the total cost of sorghum production. The t-test result

showed that there was a significant difference between the two groups of households at 1 % level of significance (Table 6).

4.1.4. Demographic Characteristics

Age and family size of the sample households: Age is one of the important factors which determine management experience of the farmers. Therefore, it is vital to discuss age of farmers within the sample. Average age of sample household heads was 48.84 years with a range of 27 to 70 years. The survey result indicated that 65.4% of the household heads age range of 35 up to 55 years and 31.49% of the household heads found to be above the age of 55 years. Additionally 3.11% of the household heads were found to be below 25 years. This indicates that most of the household heads were within their productive age group. The t-value result indicated statistically significant difference in the mean age between market participant and non-participant households which was 51.01 and 48.42 years, respectively.

Participant households were younger than non-participant, and the implication would be the former have taken the advantage of physical capacity in resources allocation, risk management, gathering market information and have more extension contacts which allow them to find out trading partners with a lower cost than the latter. The survey data indicates that, the average household size of sample household is 5.79 with minimum of 1 and maximum of 10 members. While the non participant and participant family size of farm household had 6.51 and 5.64 members, respectively. Using the t-test method, the mean difference of family size between non participant and participant household was found statically significance at 1% significance level (Table 7).

Education and sex of the sample household heads: Education enhances the acquisition and utilization of information on improved technologies by farmers as well as their innovativeness. Education together with increased experience could guide farmers to better manage their farm activities which increase their production efficiency and supply to the market. The educational level of the household heads, on average, was 4.31 years with the minimum of zero and maximum of 10. Additionally, most of the sample farmers were male headed (80.62%) and 19.38% of the sample farmers were female headed (Table 7).

Table 7 Demographic characteristics of sample household

Variables		Non participants		Market participants		Both		(χ^2)/t-test
		Mean	Std	Mean	Std	Mean	Std	
Age		51.01	10.3	48.42	8.73	48.84	9.03	1.79
Family size		6.51	1.75	5.64	1.71	5.79	1.74	3.18
Education		2.41	2.76	4.29	3.29	4.29	3.31	-4.41
Sex	Female	28.57%		71.43%		19.38%		7.73
	Male	13.30%		86.70%		80.62%		

4.1.5. Institutional Factors

Accesses to training: The most important information dissemination method in the study area was through training. General training has been given to the selected farmers and development agents by, Humera Agricultural Research Center, Axum University and Nongovernmental organization through WARDO. The trained development agents and farmers also train other farmers at each kebele level. From the sample sorghum producers, 60.55% households obtained training in the production year. The mean technical efficiency of sorghum producer households for trained and non-trained farmers was 83.33 percent and 69.88 percent respectively. The mean difference of TE between trained and non-trained household was found statically significance at 1% significance level. Additionally the mean EE and volume of sorghum supplied to market of trained households were 45.35% and 64.64 quintal respectively and also mean EE and volume of sorghum supplied to the market of non-trained households were 31.55% and 18.29 quintal in the same way. The mean difference in both economic efficiency and volume of sorghum supplied to market between trainer and non-trainer were found statically significant at 1% significance level (Table 8).

Table 8 Relationship of training with level of production efficiency among the households

Variables	Trained		Non trained		Total		t-test
	Mean	Std	Mean	Std	Mean	Std	
TE	0.8331	0.0957	0.6988	0.1334	0.7801	0.1297	-9.96
AE	0.6571	0.0853	0.6489	0.0611	0.6521	0.0853	0.791
EE	0.4535	0.0873	0.3155	0.0717	0.3991	0.1058	-14.07
Sold Qt	64.64	56.87	18.29	20.12	49.39	52.39	-9.26

Amount of credit obtained: Credit may reduce the effect of financial constraints and able to buy the necessary inputs which improves their sorghum productivity more readily than those with a small amount of credit. Therefore, it is expected that amount of credit can increases the production of agricultural crops in general and sorghum in particular. Even if credit services enhance the productivity level of farmers, there is lack of attention to access and availability of credit from formal institution rather than borrowing from informal sources (friends, relatives and illegal money lenders). On average farmers missed amount of credit ranges from 0 to 20000 birr with average 6504.1 birr. However, on average individual household receive 14377.16 birr credit and it ranges from 0 to 30000 birr. The t-test mirrors that there was a statistically significant difference between the two groups in view of this important variable (Table 9).

Frequency of extension contact: The rural extension services are the major grass-root for providing extension service delivery through the farmers training centre (FTC). Accordingly, extension service was mainly delivered by the woreda office of agriculture. Each sample kebeles had three development agents assigned to work in crop production, animal science and natural resource management. The Regional Agricultural and Rural Development Bureau gives special attention in technically supporting production activates starting right from land preparation, fertilizer application, seed selection, water conservation management, disease and pest up to post harvest handling. Frequency of extension contact provision was expected to have direct and indirect influence on the production efficiency and marketing behavior of the farmers. The mean extension contact frequency provided for sorghum producing farmers was found to be 2.75 per production season with standard deviation of 1.72. The t-test indicates that there was a statistically significant difference between the market participant and non-participant in (Table 9).

Table 9 Institutional of factors sample households

Variables	Non participants		Market participants		Both		t-test
	Mean	Std	Mean	Std	Mean	Std	
Credit birr	11553.19	6161.1	14925.62	7000.5	14377.16	6973.26	-3.08
Missed credit birr	7597.45	3672.25	6477.71	4595.45	6504.1	3668.85	1.57
Extension service	1.57	1.08	2.98	1.73	2.75	1.72	-5.37

4.1.6. Resource Endowment of the Sample Households

There are numerous households own resources that might have direct or indirect effect up on agricultural production efficiency and volume of supply to market. Household resource endowment may tell the wealth status of a specific household. Additionally, endowment of resources is used as input purchasing stocks, risk copping during loss of production and help to adopt multiple crop production. For instance, a household owning an iron sheet roofed house is obviously better in wealth than that owns a grass roofed house. Moreover, households who have higher holding of livestock (TLU) were expected to cultivate their plot better than those who do not possess. The major sample households' resources endowments are like plowing tool, type of house owned, non/off-farm income and land holding.

Table 10. Resource endowment of sample households

Variables	Non participants		Market participants		Both		t-test
	Mean	Std	Mean	Std	Mean	Std	
Land holding hectare	5.13	1.73	8.01	2.96	7.53	2.98	-6.41
Livestock (TLU)	12.62	4.36	15.63	3.98	15.14	4.19	-4.67
Off/non farm income (Birr)	11398.5	10200.74	19118.19	15344.47	17862.74	14892.67	-3.31

Land: Crop production requires primarily the availability of suitable cultivable land. Land is the most crucial resource, as it is a base for any economic activity especially in agricultural sector. Land size ownership influences household's decision to grow a variety of crops useful as food; and cash sources for the family. It is also vital resource that drives the household's stimulates to produce and supply more to market. Analysis of survey data (Table 10) depicts that the mean land holding of market participate households were 8.01 hectares with 2.96 standard devotion and the non-market participant were 5.13 hectares with 1.73 standard devotion. Using the t-test method, the mean difference of land holding between market participant and non-participant households were found statically significant at 1% significance level.

Livestock ownership: Production is an integral component of the farming system. Farming in the study area is characterized by mixed farming system. Livestock rearing is an important component of the farming system also one of the major agricultural activities for farm households in the study districts. Livestock serves for cash income generation farm households next to crops in the district and supplies multiple purposes. Donkeys are used for transporting of water and other goods to the market. Poultry is kept for egg and meat production for both cash and home consumption. Cows are important sources of milk and milk products for consumption and satisfy immediate cash through sales of butter. Animal manure is used as fertilizer for crop production and dried dung is used as source of energy for cooking. Estimation of the livestock holding of each household was done by calculating in Tropical Livestock Unit (TLU). An average livestock holding of household was 15.14 TLU with standard deviation of 4.19. The mean livestock holding for participant and nonparticipant households were 15.63 and 12.63 respectively. Among the variables indicated in Table 10, livestock holding was found statistically significant at 1% probability level

Off/non-farm activities: Farmers in the study area are engaged in various off/non-farm activities in parallel with the main farming activities throughout the season. Some of these activities are; renting house, petty trade, butchery, grinding mills, handicraft, selling of local drinks, pension and serve as guard. The mean total income of household in the sample was 17862.74 birr with standard deviation of 14892.67 birr. The income of the sample households ranges from 0 up to 68760 birr minimum and maximum respectively. Using the t-test, the mean difference of off farm income between market participant and non-participant household was found statically significance at 1% significance level (Table 10).

4.2. Econometric Model Outputs

This section presents the econometric models outputs of the study. In this section, the production function, individual efficiency scores and sources of differences in sorghum production inefficiency and volume of sorghum marketed in the study area are analyzed and discussed.

4.2.1. Tests of Hypothesis

Before proceeding to the estimation of the parameters from which individual level of efficiencies are estimated, it is essential to check various assumptions related to the model specification. To do this, hypotheses were tested. The first test was to examine whether the average production function (without considering the non-negative random error term) does not fits the data so as to verify there exists considerable inefficiency among farmers in the production of sorghum in the study area based on the equation . The other hypothesis was to check whether the explanatory variables in the inefficiency effect model contribute significantly to inefficiency variation for the sorghum producing farmers or they are efficient and have no room for efficiency improvement. The test was made by generalized likelihood ratio statistic, Log likelihood Ratio (LR) which is defined as $\lambda = LR = -2[\ln(H_0) - \ln(H_1)]$ where $\ln(H_0)$ and $\ln(H_1)$ are the values of log likelihood function of the null and alternative hypothesis, respectively as stated in Coelli and Battesse (1996).

Table 11 Generalized likelihood ratio tests of hypothesis for the parameters of the SPF

Null hypothesis	Degree of freedom	LH_0	LH_1	Calculated $\chi 2$(LR) value	Critical $\chi 2$ value	Decision
H_0: = $\beta_{ij} = 0$	35	34.08	58.4	48.63	50.89	Accept
H_0: $\gamma = 0$	1	-264.5	34.08	597.16	3.84	Reject
H_0: $\lambda = \delta_1 = \ldots \delta_{12} = 0$	12	152.49	34.08	-236.82	28.29	Reject
H_0: = $\mu=0$	1	34.084	34.091	0.0132	3.84	Accept

The first test was the null hypothesis that identifies an appropriate functional form between restrictive Cobb-Douglas and the non restrictive Translog sorghum production function. Which specifies the null hypothesis is the coefficient of interaction and square terms are equivalent to zero. The Cobb-Douglas and the Translog functional forms are the most commonly used stochastic frontier functions in the analysis of production efficiency. The Translog frontier function turns into Cobb-Douglas when all the square and interaction terms in the Translog are zero. In order to choose between the two alternative functional forms that can better fit to the survey data collected, the null hypothesis that all the interaction and square terms are all equal to zero (H_0: $\beta_{ij} = 0$), that is Cobb-Douglas frontier functional specification,

is tested against the alternative hypothesis that these coefficients are different from zero (H_1: $\beta_{ij} \neq 0$).

The result presented in Table 11 indicates the calculated likelihood ratio value (LR) equal to 48.63 while the critical likelihood ratio value at 28 degree of freedom equals to 50.89. Since the calculated LR value is less than the critical value of chi- square at 28 degree of freedom, the null hypothesis is accepted at 1% level of significance implying that Cobb- Douglas functional form adequately represents the input output data of sorghum production.

The second test was to check for the existence of the inefficiency component of the total error term of the stochastic production function. Using Cobb-Douglas functional form and assuming a half-normal distribution of one-sided error term (u_i), the hypothesis to be tested was whether economic inefficiency is absent in the model and hence the conventional (average) production function is appropriate or not. If the one-sided error term is equal to zero then the stochastic model is identical to the average response function (OLS) indicating that there is no efficiency differentials among the farmers.

Tests of hypotheses for the parameters of the frontier model are conducted using the generalized likelihood ratio statistics, λ. The test statistics is presented in Table 11. Here, the likelihood ratio test is used 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 is greater than zero ($\gamma > 0$) where $\gamma = \sigma_\mu^2 / \left(\sigma_\mu^2 + \sigma_v^2\right)$. Thus, the likelihood ratio is calculated and compared with the $\chi 2$ value at a degree of freedom equal to the number of restrictions (the inefficiency component, γ) estimated by the full frontier. The one-sided LR- test of the model ($\gamma = 0$) provides a statistic of 597.16 which is significantly higher than the critical value of $\chi 2$ at 1% level of significance. Rejecting the null hypothesis implies that the average response function estimated by OLS, which assumes that producers are fully efficient and inefficiency effects are absent from the model is an inadequate representation of the data. Consequently, the null hypothesis that sorghum producers in the area are fully efficient is rejected.

The third hypothesis test was that all coefficients of the inefficiency effect model are simultaneously equal to zero. It is to mean that the explanatory variables in the inefficiency effect model do not contribute significantly to the explanation of the inefficiency variation for

the sorghum producing farmers. (H0: $\delta 1 = \delta 2 = \ldots = \delta 12 = 0$) against the alternative hypothesis, which states that all parameter coefficients of the inefficiency model are different from zero. In other words, whether production inefficiency is present in sorghum production or not was tested. It was also conducted in the same way by calculating the LR 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 inefficiency level of each farmer, H1).

The result presented in Table 11 above indicates that the calculated likelihood ratio value (LR) equals to -236.82 while the critical chi-square value at 1% level of significance equals to 28.29. Since the calculated likelihood ratio value (LR) is greater than the critical value of chi-square at 1 degree of freedom, the null hypothesis is rejected at 1% level of significance. As a result, the null hypothesis is rejected in favor of the alternative hypothesis that explanatory variables associated with inefficiency effects model are simultaneously different from zero.

The fourth test conducted was, given such functional forms for the sample households; it was considered whether the technical efficiency levels were better estimated using a half normal or a truncated normal distribution of μ_i The results indicated that the half normal distribution was appropriate for the sample households in the study area as the calculated LR ratio value of 0.013 was less than the critical χ^2-value of 3.84 at 5% significance level. That means the null hypothesis (H_0: $\mu=0$ distribution assumption) was accepted at 5% significance level.

4.2.2. Estimation of Stochastic Frontier Production Function (SFPF)

The maximum likelihood (ML) estimates of the parameter of the stochastic frontier Cobb-Douglas production function results are presented in Table 12. The standard OLS estimate is also presented for comparison. As described in the data analysis of the methodological part, the specified Cobb-Douglas functional form of the stochastic frontier model with half-normal distributional assumption of the error terms is considered to estimate the model or parameters of the model. The maximum-likelihood estimates of parameters of the stochastic production frontier a model was described equations (3.2). After testing the dataset a stochastic production frontier model permits to consider production of sorghum in the study area with a Cobb-Douglas type of production function.

The result of the model showed that all the input variables in the production function except seed had a positive and significant effect on the level of sorghum output. The interpretation of the parameters that entered the production function directly is given in the form of partial production elasticities that examines the degree of responsiveness of relative change in sorghum output due to relative change in each input. These serve as a measure of resource productivity. Hence, the point estimates indicated in Table 12 shows that 1% increase of land, plow power, DAP, urea, chemical and labour will increase sorghum output by 0.316%, 0.123%, 0.263%, 0.104%, 0.048% and 0.319% respectively.

Table 12 Estimation of stochastic frontier production function

Ln sorghum production	Unit	OLS estimated model		ML estimate half normal model	
		Coefficient	Standard error	Coefficient	Standard error
LnSeed	Kg	0.042	0.101	0.058	0.077
LnLand	Ha	0.316**	0.133	0.306***	0.106
LnPlow power	Hour	0.123***	0.123	0.103**	0.045
LnDAP	Quintal	0.263***	0.054	0.187***	0.056
LnUrea	Quintal	0.104*	0.058	0.116**	0.053
LnChemical	Litter	0.048	0.056	0.102*	0.058
Lnlabour	Man day	0.319***	0.078	0.322***	0.065
Constant		1.919***	0.386	2.086***	0.325
Lamda (λ)		-	-	3.358***	0.053
Sigma (δ^2)		-	-	0.123***	0.018
Gamma(γ)		-	-	0.919	
LR		-	-	34.08	
F statistics		427.08***			
Adjusted R^2		0.911			
Returns to scale				1.194	

NB: *, **, ***, Significant at 10%, 5% and 1% level of significance

The Maximum Likelihood estimation of the frontier model gives the value for the parameter (γ), which is the ratio of the variance of the inefficiency component to the total error term is equal to $\gamma = \sigma_\mu^2 / \left(\sigma_\mu^2 + \sigma_v^2\right)$ or $\lambda^2 / 1 + \lambda^2$ (Bravo and Pinheiro, 1997). The γ value indicates the relative variability of the one sided error term to the total error-term. In other words, it measures the extent of variability between observed and frontier output that is affected by the technical inefficiency. The closer ratio to one indicates more variability of the output affected by technical inefficiency than the usual random variability.

Estimated value of gamma was 91.85% which indicated that variation in sorghum farm output was due to technical inefficiency. The value of σ^2 for the frontier of sorghum output was 0.123 which was significantly different from zero s at 1% level of significance. The significant value of the sigma square indicates that the goodness of fit and correctness of the specified assumption of the composite error terms distribution as indicate in (Jondrow *et al.* 1982, Idiong, 2005; Okoye *et al*., 2007).

4.2.3. Partial Elasticity and Returns to Scale

Elasticity of production: It measures the effect of change in the factor input on output. In Cobb-Douglas production function, the regression coefficients stand for the elasticity's of the individual resources (Land, Labor, Seed, Urea, DAP, Chemical and Tractor power).The elasticity of production which is the percentage change in output as a ratio of a percentage change in input was used to calculate the rate of return to scale. It measures a firm/farm's success in producing maximum output from a set of input as stated in Farrell (1957). Parameter estimates from the Cobb-Douglas production function represent output elasticity with respect to the individual inputs. The output elasticity was calculated as:

$$\varepsilon = \frac{\partial \ln Y}{\partial \ln X} = \beta_i \ln X$$

Where ε is the output elasticity with respect to the individual inputs and X_i = 1, 2….7 for the seven individual inputs.

The returns to scale, from neoclassical theory of economics is used to show the proportionate increase in output resulting from a given proportionate increase in all inputs. The returns to

scale can be either of increasing, decreasing or constant, if the sum of the estimated partial elasticities is greater than, less than or equal to one respectively. The summation of the partial elasticities $\left(\sum \varepsilon_p\right)$ of all the inputs is 1.19. This implies that increase in all inputs at the sample mean by one percent may lead to increased production by 1.19 percent, ceteris paribus, i.e. sorghum producers in the study area were operating at increasing returns to scale of production (Table13). The result is in line with results found by Haileselasse (2006) and Gosa (2016)

Table 13 Partial elasticity and returns to scale

Variables	Elasticity of production
LnSeed	0.058
LnLand	0.306
LnPlow power	0.103
LnDAP	0.187
LnUrea	0.116
LnChemical	0.102
LnLabour	0.322
Return to scale	1.19

4.2.4. Efficiency of Sorghum Producers

Efficiency score indicates the existence of room for improving the existing level of production through enhancing the farmer's efficiency using the existing limited resources by improving the firm capacity to utilize available resources in efficiently in order to get maximum production.

Table 14 Efficiency score of sorghum producers

Types of efficiency	Non participants		Market participants		Both		t-test
	Mean	Std	Mean	Std	Mean	Std	
Technical	0.757	0.138	0.785	0.128	0.780	0.129	-1.32
Allocative	0.624	0.093	0.657	0.083	0.652	0.085	-2.46
Economic	0.461	0.035	0.510	0.073	0.502	0.071	-4.49

The result presented in Table 14 shows that the mean allocative efficiency of farmers in the study area was 65.21 percent. This result indicated presence of room to improve the present level of allocative efficiency. Moreover, estimates indicated that farmers have abundant opportunities to increase their allocative efficiency. For instance, farmer with average level of allocative efficiency would have a cost saving of about 32.91 percent derived from $(1-0.6521073/0.971973)*100$ to attain the level of the most efficient farmer. The most allocative inefficient farmer would enjoy an efficiency gain of 60.31 percent found from $(1-0.385848/0.971973)*100$ to attain the level of the most technically efficient farmer

The mean economic efficiency also showed that there was a significant level of inefficiency in the production process. That is the producer with an average economic efficiency level could reduce current average cost of production by 49.80 percent 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 percent economic efficiency, they would experience substantial production cost saving of 49.80 percent. This implied that reduction in cost of production through eliminating resource use inefficiency could add about 49.80 percent of the minimum annual income. Moreover, the result also means that the farmer with average level of economic efficiency would enjoy a cost saving of about 23.14% derived from $(1-0.5022105/0.6533746)*100$ to attain the level of the most efficient farmer. The most economically inefficient farmer would have an efficiency gain of 68.22 percent derived from $(1-0.1596029/0.5022105)*100$ to attain the level of the most efficient farmer (Table 14).

According to the result, efficiency scores show that there were wide ranges of differences in technical efficiency among sorghum producer farmers in the study area. The mean technical efficiency of sample households during the survey year was 78.01 percent. The technical efficiency among farmers ranged from 39.86 to 96.64 percent. This shows that there is a wide disparity among sorghum producer farmers in their level of technical efficiency which may in turn indicate that there is a room for improving the existing level of sorghum production through enhancing the level of farmers' technical efficiency (Table 14). This wide variation in farmer technical efficiency levels is consistent with study of (Jema, 2016; Mussa, 2013; Mohamed, 2012; Essa, 2011).

On the other hand, mean level of technical efficiency further tells us the level of sorghum output of the sample respondents which can be increased on average by about 21.87 percent if appropriate measures are taken to improve the efficiency level of sorghum growing farmers. This point out that presence of an opportunity to increase yield of sorghum approximately by 21.87 percent using the existing resources at their disposal in an efficient manner without introducing any other external inputs and practices.

4.2.5. Individual Farmer's Frequency Distribution of Production Efficiency

Table 15 Production efficiency levels

Efficiency	Technical efficiency		Allocative efficiency		Economic efficiency	
range	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
00 - 10.999	0	0	0	0	0	0
11 - 20.999	0	0	0	0	2	0.69
21 - 30.999	0	0	0	0	7	2.42
31 - 40.999	1	0.35	1	0.35	156	53.98
41 - 50.999	6	2.07	12	4.15	95	32.87
51 - 60.999	29	10.03	46	15.92	29	10.03
61 - 70.999	36	12.46	162	56.06	0	0
71 - 80.999	66	22.84	57	19.72	0	0
81 - 90.999	89	30.80	6	2.08	0	0
91 – 100	62	21.45	5	1.73	0	0

The level of TE of sample sorghum producer households is presented in Table 15. About 30.80 percent of sorghum farmers in the study area were operating in the range of 81 up to 90 percent of technical efficiency level. On the other hand, none of the farmers were operating below 30 percent technical efficiency level. However, 44.29 percent of the sample farmers were operating below the overall mean level of technical efficiency while about 55.71 percent of the sample farmers were operating above the mean technical efficiency level.

The distribution of AE scores implied that 56.06 percent of farmers were performing between 61 to70 percent allocative efficiency levels. On the other hand, 52.59 percent of the sample

farmers were operating below the overall means allocative efficiency level. At the same time about 47.41 percent of the sample farmers were operating above the mean level of allocative efficiency. The distribution of EE scores implied that 53.98 percent of sample farmers are performing between 31 up to 40 percent economic efficiency level. On the other hand 58.13 percent of the sample farmers were operating below the overall at the same time about 41.87 percent of the farmers were operating above the mean level of economic efficiency (Table 15). Economic efficiency level was higher compared with the results obtained by Jema (2016), Mussa (2013), Mohamed (2012) and Essa (2011).

4.2.6. Actual and Potential Levels of Output

The knowledge of the individual farmer efficiency level and their corresponding actual output enables us to determine how much yield is lost because of inefficient use of existing resources. From the current production practice of the existing resources, it is possible to find out the potential attainable level of sorghum output or yield. Either the farmers had used the available resources in an efficient way was calculated using the actual observed individual level sorghum output and predicted individual TE from the frontier model.

From the relationship of technical efficiency in a given period of time as the ratio of the actual output $\left(Y_i ; \exp\left(X_i\beta + \nu_i - \mu_i\right)\right)$ to the potential output $\left(Y_i^* ; \exp\left(X_i\beta + \nu_i\right)\right)$ described in equation, the potential sorghum production of each individual farmer is calculated as follows: $TE_i = Y_i / Y_i^* = \exp\left(-\mu_i\right)$ which gives $Y_i^* = Y_i / TE$. The mean level of both actual and potential output during the production year were 18.35qt/ha and 23.16 qt/ha with standard error of 6.48 and 5.86 respectively. Using the t-test method, the mean difference of the actual and the potential output was found to be statistically significant at 1% provability level. The result is similar with the results found by Haileselasse (2006), Essa, (2011) and Gosa (2016).

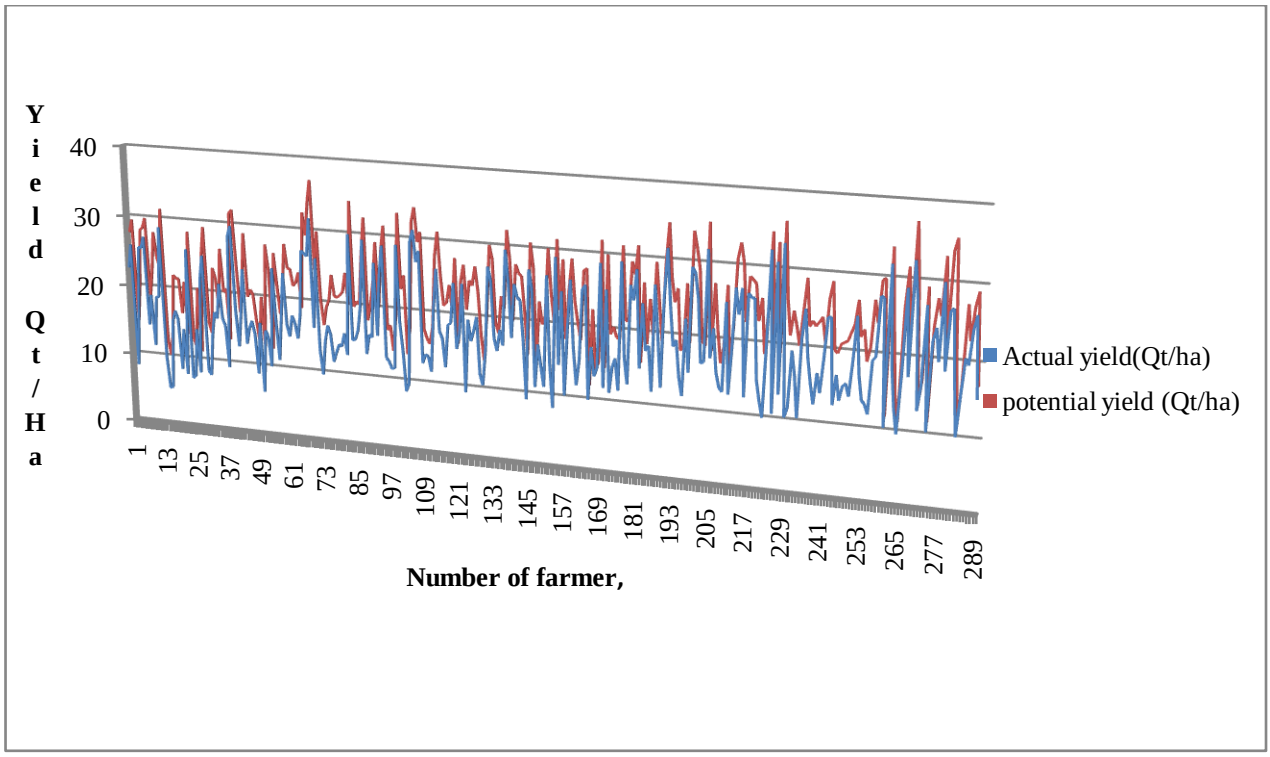

Figure 4 Comparison of actual and potential levels of output

4.2.7. Stochastic Frontier Cost Function (SFCF)

The parameters of the stochastic frontier production function are actually used to derive the parameters of the dual cost function. Adjusted output is used to derive allocative and economic efficiencies employing the dual cost frontier function. Where C 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, W stands for input prices (Sharma *et al.*, 1999; Bravo-Ureta and Rieger, 1991 and Aigner *et al.*, 1977). On account of inadequate farm level price data coupled with little or no input price variation across farms in the study area precludes any econometric estimation of a cost or profit frontier function. Therefore, the use of self-dual production frontier functions allows the cost frontier to be derived and used to estimate economic efficiency in situations where producers face the same input prices.

$$lnC_i = 2.832 + 0.256lnW_1 + 0.049lnW_2 + 0.086lnW_3 + 0.157lnW_4 + 0.112lnW_5 + 0.085lnW_6 + 0.838lnY^*$$

4.2.8. Determinants of Efficiency Disparities among Farmers

After measuring levels of efficiency and determining the presence of efficiency variation among farmers, the main interest behind measuring efficiency level was to know the factors that determine the efficiency level of individual farmers. The parameters of the various hypothesized variables in the efficiency effect model that were expected to determine efficiency differences among farmers were estimated using second stage estimation procedure. The determinants of technical, allocative and economic efficiencies in a given period differ considerably depending on the demographic, socioeconomic, farm, institutional and environmental conditions of the study area.

The result of regression model also showed that among the total variables age, age^{2,} education, off farm income, amount of credit obtained, total livestock holding, training and extension service significantly affects the level of technical efficiency. Whereas age, age^{2,} education, off farm income, amount of credit obtained, extension service and frequency of farm visit significantly influence allocative efficiency of sorghum production. Additionally age, age,^{2} education, off farm income, amount of credit obtained, extension service and frequency of farm visit factors were important in influencing economic efficiency of households in the study area.

4.2.9. Determinates of Technical Allocative and Economic Efficiency of Sorghum Production

Table 16 Factors influencing technical efficiency, allocative efficiency and economic efficiency

Variables	Technical efficiency		Allocative efficiency		Economic efficiency	
	Marginal effect	Std. Error	Marginal effect	Std. Error	Marginal effect	Std. Error
Age	0.02159***	0.00441	-0.00841*	0.00482	0.01209***	0.00286
Age^2	-0.00023***	0.00005	0.00009*	0.00005	-0.0001***	0.00003
Education	0.00624***	0.00225	0.00714***	0.00242	0.00359*	0.00215
Family size	-0.00175	0.00218	-0.00017	0.0024	-0.00194	0.00142
Sex	0.00461	0.01162	0.02023	0.01276	0.00708	0.00755
Lnoff income	0.00425***	0.00066	-0.00359*	0.00195	0.00185***	0.00043
LnCredit	0.00545***	0.00092	-0.00595***	0.00101	0.00131**	0.0006
Livestock (TLU)	-0.01238**	0.00679	0.00212	0.00387	-0.00161	0.00229
Extension contact	0.03711***	0.00349	-0.00979*	0.00383	0.03343***	0.00227
Training	0.02143*	0.01125	-0.00248	0.01236	-0.00836	0.00731
FSize other	0.00277	0.00179	-0.00223	0.00197	0.00126	0.00116
Frequency farm visit	0.00714	0.00485	0.00916*	0.00478	0.01203**	0.00283
Constant	0.37585**	0.15280	0.67698***	0.11965	0.63531***	0.10634

NB: *, **, ***, Significant at10%, 5% and 1% level of significance

Age of household head: Age of household head had significant and positive effect on technical and economic efficiency of sorghum producing farmers at one percent level of significance. This indicates that as the age of farmers increases their inefficiency decreases which leads to improvement in the level of technical and economic efficiency. This may be due to the fact that age can serve as a proxy variable of farming experience, in which farmers with more years of experience are expected to be less inefficient. The result is in conformity with the results of Gosa (2016), Mustefa (2014) on Barley and Mohammed (2012) sorghum in Nigeria. However, this may diminish, as the household head gets older. The result shows that the age and age-square have positive and negative signs, respectively and both are significant (Table 16). Thus, middle aged farmers are more efficient than the very young and older ones. Since farming as any other professions need accumulated knowledge, skill and physical capability, it is decisive in determining efficiency. The result is similar with Haileselasse (2006).

However, the negative coefficient of age of household head, which is significant in allocative efficiency, indicates that efficiency in resource allocation is deteriorating when the household gets older at 1 percent significance level. Age contributed negatively to the allocative efficiency in this study; in other words, younger farmers were relatively more efficient than older farmers. The reason could be younger farmers had more contacts with extension agent services, plot demonstration and agricultural meetings. This result is in line with Gosa (2016) in Habro and Tukela *et al* (2014) in Sidama on sorghum and maize respectively.

Age and age-square have negative and positive effect in allocative efficiency respectively. In addition to this age changes the general farming experience and physical capacity of farmers, which in turn brining differences in abilities of decision making and laborious farming practices. These efforts again could create efficiency differential across the different age. The reason could be because of the accumulated experiences that have been gathered over time. They become skillful as they get older and may have an interest in the use of new methods of production. The estimated coefficients of age square for allocative were also positive and significant at 1 percent significance level. This may be because allocative efficiency requires greater knowledge and skill gained over time, which builds the capacity of farmers for optimal allocation of resources and technology.

Frequency of extension contact: It had statistically significant positive relationship with technical and economic efficiency at one percent significance level. This implies that frequent extension service facilitates the flow of new ideas between the extension agent and the farmer thereby giving a room for improvement in farm efficiency. Advisory service provides to the farmer to improve their average performance in the overall farming operation. As the service widens the household's knowledge with regard to the use of improved agricultural inputs and agricultural technologies will increased. This result is also conformity to those results obtained by Mohammed (2012) in Nigeria, Chepng'etich (2013) in Kenya and opposite to Kusse (2016) and Haileselasse (2006) on sorghum. However, the negative coefficient of extension contact which is significant at ten percent in allocative efficiency indicates that efficiencies in resource allocation is hindering as the frequency of extension service increases. This may be due to the fact that extension workers are only interested in maximizing output at any cost. This result is similar with result obtained by Jema (2008) on vegetable, Musa (2013) on maize and Ermias *et al*. (2015) on sesame Hika (2016) on sesame.

Education: Education is believed to enhance the managerial and technical skills of farmers. It had significant and positive effect for all efficiencies. The positive and significant effect of education on all types of efficiencies verifies the importance of education in increasing the efficiency of sorghum production. Education can be a proxy variable for managerial ability of the farmer and improves the ability of the household to make better decision about production inputs. Because of their better skills, access to information and good farm planning; literate farmers are better to manage their farm resources and agricultural activities and willing to adopt improved production technologies than illiterate one. Education increases technical efficiency of sorghum producer farmers in the study area. This result is in line with early study of, Solomon (2014) on major crop; Assefa (2012) on crop producing smallholder farmers and Zalkuwi *et al*., (2014) on sorghum.

Additionally educated farmers have also relatively better capacity for optimal allocation of inputs. This result is in line with result obtained by Endalkachew (2012) on barely and Sisay (2015) on maize Gosa (2016) and Kifle *et* al. (2017) on maize. This result indicates that access to better education enabling farmers to enhance their managerial ability in resource use in order to produce optimum level of output. This indicates education capacitating human capital

that enhances the productivity of farmers by allocating homemade and purchased inputs, select the appropriate quantities of purchased inputs and choose among available techniques.

Off/non-farm income: It had statistically significant positive relationship with technical and economic efficiency at one percent significance level. This implies that off/non-farm income occupation enhances the technical and economic efficiency of sorghum producers. Off/non-farm occupation may affect the technical efficiency positively for the reason that the income obtained from such activities could be used for the purchase of agricultural inputs and enhances financing of household expenditures which would entirely dependent on agriculture. This result is in line with previous results of Haileselasse (2006), Jema (2008); Abebayehu (2011) and Hasen *et al.* (2012).

It is also positive and significant at 1 percent for economic efficiency. This may be because; the availability of off/non-farm income shifts the cash constraint outwards and enables farmers to make timely purchases of those inputs which they cannot obtain from on farm income. Therefore, it may enable farmers in maximizing their output at low cost of production. This result is also in conformity to results obtained by Ermiyas (2013) on sesame and Kifle (2014) on maize. The negative and significant effect of off-farm income on allocative efficiency indicated that farmers engaged in off-farm income earning activities tend to exhibit lower level of allocative efficiency. According to this study, involvement in non-farm activities were accompanied by reallocation of time away from farm related activities, such as adoption of new technologies and gathering information that is essential for enhancing allocative efficiency. This result is in line with results found by Bealu *et al*. (2013) on maize and Ermiyas (2013) on sesame.

Credit: Credit utilization is an important element in agricultural production systems. It allows producers to satisfy their cash needs induced by the production cycle in different agricultural practices. Credit increases farmer's efficiency because it temporarily solves shortage of liquidity/working capital. In this study, credit is found to have positive and significant relation with technical and economic efficiency, which indicates that farmers with access to credit tend to exhibit higher levels of efficiency. Credit availability shifts the cash constraint outwards and enables farmers to make timely purchases of those inputs that they cannot provide from their own sources. This result is in line with Hasan (2006); Jude *et al.* (2011) and Gbigbi

(2011).However, the negative coefficient of credit utilization which is significant in allocative efficiency indicates that as compared to those households who credit utilizes it reduces allocative efficiency. This may be because of fearing repayment which did not consider risk, Changing weather condition, non-existence of agricultural insurance and level of loan diversion problem and inappropriate use of funds by farmers for agricultural production purpose. This result is in line with the argument of Ibrahim (2018) in Sudan on sorghum and millet.

Livestock holding (TLU): Livestock in a mixed farming system have importance in the supply of animal power for plowing and threshing, provide draught power, manure, fire energy, and they are sources of income and food for the family. It can also be a proxy variable for the wealth status of the farmer. As livestock could have both competitive and complementary relationship with crop production, the direction of influence on production and efficiency depends on which form of the relationship outweighs under the considered study area. The result indicated that there was a negative sign and significant impact of total livestock holding on TE. The negative effect of total livestock holding indicates that a farmer with large populations of livestock ownership were less efficient in the study area. The reason might be that livestock husbandry may compete for resource with crop production and hence did not improve production. This result is in line with the argument of Fekadu (2004); Kinde (2005) and Bealu *et al.* (2013).

Training participation: The coefficient of training participation in sorghum production was significantly affecting the technical efficiency at households' level in Kafta humera woreda. It was a dummy variable and significant at 1% significance level. May the reason was giving training increases the awareness of farmers and exposes to new ideas and information about productivity of inputs, opportunities, input and output management and prudent handling of cash. Those households who attend trainings on various sorghum production skills can easily adopt various sorghum production technologies. Farmers who received training were technical more efficient than those who did not received training. This result was related with the result found by Fekadu (2004) on wheat, Hagos (2014) on major crops and Bealu *et al*. (2013) on maize.

Frequency of sorghum farm visit: It is found that this variable significantly and positively determines the allocative and economic efficiency of sorghum production at 10% and 5% significance levels respectively. This result indicates that as the frequency of farm visit increases the efficiency level of farmer increases. This may be the reason follow up it enables farmers to understand and quickly solve the possible solutions which boosts productivity.

4.2.10. Determinates of sorghum supply to the market

Sorghum is produced by households mainly for consumption, seed and income generating through supply to the market in the study areas. However, various variables were assumed to determine the marketed surplus by sampled households. The purpose of this section is also to identify the hypothesized independent variables that influence the volume of sorghum supply. Tobit model was employed to answer the questions of identifying the factors determining the supply of sorghum. As observed from the econometric result in (Table 17), 15 hypothesized explanatory variables (13 continuous and 2 dummy) were included in the model to identify factors affecting the volume of sorghum marketed. Out of these variables, seven were found significantly influence volume of sorghum marketed. These variables include perception of farmers toward sorghum and sesame market price, family size, education, amount of credit, livestock holding (TLU), access of training and land allocated sorghum production.

The result from descriptive showed that 74.45% of sorghum production or 83.73% of respondents supplied the commodity to markets. The likelihood of households to sell their sorghum in the output markets was 67.99%, which is clearly different from the descriptive or proportion test results (83.74% = 242/289).On the other hand, among the 289 sample households, (16.26%= 47/289) of them did not supply sorghum to the market. The values of dependent variable for these observations were zero that censored to the left.

Table 17 Determinates of sorghum supply to the market

Variables	Coefficients	Std Error	Change among the whole $\frac{\partial E(Y_i)}{\partial x_i}$	Change among the seller $\frac{\partial E(Y_i / Y_i^* > 0)}{\partial X_i}$	Change in probability $\frac{\partial F(z)}{\partial x_i} = f(z)\frac{\beta_i}{\sigma}$
Age	-0.01281	0.02463	-0.01281	-0.00612	-0.00163
Sex	0.25863	0.57926	0.25863	0.12544	0.03291
Family size	-0.5476***	0.10859	-0.54759	-0.18614	-0.06967
Education	0.20498*	0.11358	0.20498	0.09782	0.02608
Livestock(TLU)	0.05208	0.17997	0.05208	0.02486	0.00663
Lnofffarm income	-0.05024	0.03286	-0.05024	-0.02399	-0.00639
LnCredit	0.09772**	0.04431	0.09772	0.04665	0.01243
Extension	0.13408*	0.22687	0.13408	0.06401	0.01706
Training	1.41767***	0.55790	1.4167	0.97410	0.18039
Farm visit	0.05356	0.21155	0.05356	0.02558	0.00682
Ln lag Price Sorghum	-2.47069	1.88267	-2.47136	-1.44291	-0.31438
LnCurrent Price Sorghum	5.82328***	1.25772	5.82331	2.84729	0.74098
LnLagged Price Sesame	-2.54927*	1.50169	-2.55119	-1.21797	-0.32438
LnFertilizer	0.54324	0.52991	0.54324	0.25935	0.06912
LnLand	2.81985***	0.76381	2.8189	1.80074	0.35881
Constant	-40.1057**	16.4415			
Sigma	2.81285***	0.13389			
Pseudo R^2	0.2333				
LRchi^2(15)	386.91				
No Observation	289				
Left censored	47				
Uncensored	242				
Right censored	0				

NB: *, **, ***, Significant at10%, 5% and 1% level of significance

Family size: Family size was measured by the total number of family members in the household. The coefficients of family size for quantity of sorghum marketed was negative signs and significant at one percent significance level. In unit additional family member decreases the probability of quantity supplied by 6.97%. As the result the marginal effects of intensity and the whole shows that, one number increment of family size in the households decrease amount of volume of sorghum marketed by 18.61% and 54.76% sequentially. This result shows that households with larger family size tend to supply less sorghum produce to the market. This finding is in agreement with the study conducted by Wolday (1994); Abay (2007), Astewel (2010) and Fantahun (2010).

Education level of the household head (Education): Education status was measured by formal schooling of household head in years of schooling. The coefficient of education for volume of sorghum market had positive signs and significant at five percent significance level. This model output indicates that as education level of the farmer increases, the quantity of sorghum supplied to market increases. This result may be educated house hold education had improved the producing household ability to acquire new idea in relation to market information and improved production which in turn enhanced productivity and thereby increased marketable supply of sorghum. This in line with results found Astewel (2010) on rice and Ayelech (2011) on fruit.

Amount of credit: Amount of credit had positive and significant effect on volume of sorghum marketed at 5 percent significance level. The marginal effect result indicates that an increase in the amount of credit by one percent the volume of sorghum marketed increased 0.098 %. Households who had increase in one percent utilization of credit had probability to increase sorghum market participation by 1.24%. This may be utilization of credit improvise production through purchasing of inputs which are required for the production sorghum additionally repayment of credit prompt the households to increase their supply sorghum to the market. This result is in line with the works of Muhammed (2011) on wheat and Haymanot (2014) on durum wheat.

Training participation: The coefficient of training participation in sorghum production was significantly affecting the volume of sorghum supplied at households' level in Kafta humera woreda. It was a dummy variable and significant at 1% significance level. It is known that

giving trainings for producers on in sorghum production can fill the knowledge gap that constrained production and productivity. Those households who attend trainings on various sorghum production skills can easily adopt various sorghum production technologies. In addition they can produce more and then supply more relative to those households who do not attend trainings on sorghum production skills. The marginal effect result indicates that households who had access to training increases the volume of sorghum marketed by 18.04 % compared to the households who did not have access to training. Additionally the result on average, change in the access of training of the household on the quantity of sorghum supplied was 141% quintal among the whole group and 97.41% quintal among the sellers group.

Current price of sorghum: The coefficient of current price of sorghum shows a significant and positive effect on marketed surplus of sorghum at 1% significance level. It indicates that as farmers detect in the market there is an increase in price of sorghum they supply more to market. The marginal effect of result indicates that in one percent increasing in price increases the probability of quantity supplied by 74.09%. As the result the marginal effects of intensity and the whole shows that, one percent increment of current price in the households increase amount of volume of sorghum marketed by 5.82% and 2.85% quintal sequentially. This result is parallel with result of Welelaw (2005) in rice.

Lagged price of sesame: The coefficient of previous price of sesame shows a significant and negative effect on marketed surplus of sorghum at 10% significance level. It indicates that as farmers identify in the market there is an increase in price of sesame they supply less of sorghum to market in the next year. The marginal effect of result indicates that in one percent increasing in price of sesame it decreases the probability of quantity supplied by 32.44% of sorghum in the coming year. This is because these two crops are the most important crops in terms of area cultivated, use of fertilizer and hired labour, and hence there is severe competition for all resources, including land. The correlation coefficients show that there is significant competition for land between these two crops.

Frequency extension contact: Frequency of extension service had affected positively and statically significant at ten percent of significant level. This indicates that households, who had accesses every one unit of extension services it increase the probability of amount sorghum supplied to the market by 17.06% than households who had no accesses extension contact.

This may the fact that, those farmers that have frequent extension services with extension experts have better access to information and could adopt better technology that would increase their production and productivity as well as market supply of sorghum. The effort to popularize new agricultural technologies is influenced by the efficiency of communication between the development agents and the farmers at grass root level. This result is in line with results of Ayelech (2011), Mohammed (2011), Asres *et al*. (2013) and Rehima (2012).

Land allocated for sorghum: The result of this finding indicated that the amount of land allocated for only sorghum production had positive and significant influence on market supply of sorghum at 1% level of significance. Therefore, this finding indicates that one percent increase in hectare of land allocated for sorghum production increase the probability of quantity supplied by 35.88%. As the result the marginal effects of intensity and the whole shows that, one percent increment of in land allocation in the households increase amount of volume of sorghum marketed by 2.82% and 1.80% quintal in order. This finding is in line with results obtained by Bosena (2008), Kindie (2007), Alemnew (2013) and Girma (2015).

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary and Conclusion

The study aimed at analyzing production efficiency and supply of sorghum to market in the Kafta-Humera district of Tigray region Ethiopia. The study was undertaken with the specific objective of analyzing levels of technical, allocative and economic efficiency as well as, determinants of inefficiency and market supply of sorghum. The study area was selected purposively based on the level of sorghum production in the region. To address the objectives of the studies stochastic frontier approach, Tobit and simple descriptive statistics were employed.

In this study, both purposive and a multi-stage random sampling procedures were adopted to select a sample of 289 sorghum producer households that represent the population. The data were collected from both primary and secondary sources. The primary data were collected through household survey from sample households using a semi-structured questionnaire. Besides, primary and secondary data from different sources were collected and organized. Data analysis was carried out using descriptive statistics and econometric models.

The Cobb-Douglas stochastic frontier production function result shows that all input variables except seed had significant positive effect on sorghum production. The input elasticity indicated that labor, land, DAP, urea, tractor plow power and chemicals (herbicides) inputs are organized based on their elasticity respectively. This implies that sorghum production was responsive to inputs utilization (especially labor and land). The return to scale of sorghum production in the study area was 1.19 and from neoclassical theory of economics, sample farmers faced increasing returns to scale. This implies that production was in the irrational zone of production (stage I), where resource uses and production is believed to be inefficient. That is, inputs were not efficiently allocated and utilized while producing the output.

The Cobb-Douglas stochastic frontier production model was used to estimate the production and cost functions. The estimated stochastic production frontier model illustrates that land, DAP and urea, labour and tractor plow power positively and significantly affected sorghum production. The study also indicated that 78.01%, 65.21% and 50.22% were the mean levels of

TE, AE and EE, respectively. This in turn indicates that farmers can increase their sorghum production on average by 21.92% when they were technically efficient. Similarly, they can reduce their cost by 68.22% without any change from optimum level of output. This implies that, using the subsisting resource base, improved efficiency can still be achieved and there was great potential for increasing the gross output and profit with the existing level of resource base.

In the second step of the analysis, Tobit model was used to identify factors determining relationships between TE, AE and EE. Additionally, it was used to analyses factors that determine the volume of sorghum supplied to the market by smallholder farmers. The Tobit model results indicated that age, education, off/non-farm income, credit, extension contact and training positively and significantly affected TE. Age square, education and frequency of farm visit had positive and significant effect on AE. Age, education, off/non-farm income, credit, extension contact and farm visit had positive and significant effect on EE.

However, age square and livestock (TLU) negatively and significantly affected TE. Age, off/non farm income, credit and extension contact had negative and significant effect on AE. Age square had negative and significant effect on EE. In the study factors affecting amount of sorghum supplied to market at smallholder farmers level was analyzed and education, credit, extension contact, training, current price of sorghum and land allocated for sorghum had positively and significantly affected on quantity of sorghum supplied to the market. But family size and lagged price of sesame had negative effect on quantity of sorghum supplied to market.

These findings indicated appropriate policy formulation and implementation on factors that enable farmers to improve their existing level of production efficiency and quantity of sorghum supply Development programs should act upon these variables. Therefore, the following important recommendations are given below based on the study results.

5.2. Recommendations

Age of household head had a significant positive effect on technical and economic efficiency of sorghum production. The local government should arrange field days, cross-visits, creating forum for experience sharing elder households and provision of short-term training programs

so as to share the knowledge of elder households to young farmers. Using best practices of the efficient farmers as a point of reference would help setting targets in improving efficiency levels and finding the feebleness of the present farm practices. The relatively efficient farms can also improve their efficiency more through learning the best resource allocation decision from others.

Family size affected quantity supply of sorghum negatively and significantly. This indicates that within limited production large family members in households used sorghum for home consumption rather than supply to market. Therefore, intervention should be provided on teaching households on family planning to rural community. It is obvious that most farmers do not balance their family size with their income from their livelihood activities. These situations aggravated the country's food insecurity problems. Therefore, strengthening family planning is required from the government side.

The study also revealed that farm visit had a significant positively influence both allocative and economic efficiency of smallholders. Therefore, farmers should have more frequent follow his farm and effectively manage their farm activities to overcome the positive relation to efficiency. So, it is important to strengthen the initiatives for producers to visit there farm frequently during the production period. To address the constraints and improved the level of production efficiency.

Education was very important determining factor that has significant effect on both production and quantity of sorghum supply to the market in the study area. It is central to adopt and use modern agricultural technologies and practices, agricultural information and institutional accessibilities which in turn increase and improve farm household's efficiencies. Thus government has to give due attention for training farmers through strengthening and establishing both formal and informal type of framers education, farmers training centers, technical and vocational schools as farmer education would improve both production efficiencies and market supply.

The result of the study reveals that farmers who have more frequency of extension contact were more efficient than farmers with less contact both in technical and economic efficiency. However, extension contact has negative and significant contribution to allocative efficiencies.

Therefore extension agents have to give due attention in training farmers in optimal input allocation. This could done by designing appropriate capacity building program to train additional development agents to reduce the existing higher ratio of farmers to development agents as well as to provide refreshment training for development agents. This calls for the need to more effective policy support for extension services and additional efforts need to be devoted to upgrade the skills and knowledge of the extension agents.

In this study training determined quantity of sorghum marketed and technical efficiency. It was found to have a positive and significant effect on supply and technical efficiency. Providing continuous training to smallholders and follow-up smallholders' farming activities about input usage during sorghum production is very important. Extension service centers should give trainings to the farmers to increase quantity of sorghum marketed and technical efficiency. This will substantially help smallholder sorghum producers to survive and achieve food security and supply more sorghum to market. This requires more effort from government and NGOs to increase farmers' training and education on better use of inputs.

Even though non-farm income was negatively related to allocative efficiency, it had a positive effect on technical and economic efficiency. This indicates a need to introduce activities that could enhance the non-farm/off farm income of households without affecting their farm time allocation so that the farmers would be in a position to invest the required amount of resources in sorghum production Therefore, encouraging farmers to involve them self in both activities to improve their livelihood is required.

The study indicated that utilization of credit affects technical and economic efficiency positively. But it also affected allocative efficiency negatively. Therefore, better credit facility has to be facilitated via the establishment of adequate rural financial institutions and strengthening of the available micro-finance institutions and agricultural cooperatives to assist farmers in terms of finance. Additionally, improvements in farm efficiency rely on institutional capacity building for farmers. As a result, policy makers need to focus on providing institutional support to farmers rather than focusing on introducing new technologies. If the necessary technical and managerial skills are not in place, it may result in continued inefficiencies in sorghum production.

Livestock size affected technical significantly and negatively. This might be due to the fact that increase in livestock in TLU diverts farmers' efforts away from sorghum production and hence reduces efficiency of smallholder sorghum producers. This might be the case if the type of off-farm activity deprives the farmers from running his/her farm. There for it is better to design appropriate policy and strategies for improving livestock production systems by solving the shortage of feed and providing various technical and advisory support services, which in turn would time spent in livestock management and enhance the efficiency of sorghum production.

Price of sorghum is also an important factor influenced market supply of sorghum positively. Increasing production alone without reasonable selling price and market linkages cannot benefit farmers. Farmers need to be prioritized in any policy intervention for instance in price ceiling and price floor when unfair price is prevailed. Government and other development partners should facilitate conditions to encourage and strengthen coordination and cooperation among value chain actors.

Lagged prices sesame had a statistically significant effect on output levels of sorghum. This is particularly the case in competition for fertilizer, labour and land. Here, cross-price elasticities were higher in absolute terms relatively own price elasticities sorghum. This suggests that, in designing price policies, a comprehensive approach should be taken to properly account for interrelationships among two products. Because increasing the price of sesame leads to suppressing production sorghum which is the most important food crop in the local.

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7.APPENDIX

Appendix table 1 Multicollinearity test for explanatory variables supply

Variables	VIF	1/VIF
Livestock(TLU)	20.04	0.049889
Farm visit	14.37	0.069575
LnFertilizer	6.12	0.163272
Education	4.79	0.208863
LnLand allocated	4.18	0.239376
Extension	3.21	0.311793
Lnoffincome	2.74	0.365261
Training	2.47	0.404067
LnCPSorghum	1.87	0.534767
LnCredit	1.82	0.549474
Sex	1.76	0.567419
Age	1.70	0.589210
LnlagP Sorghum	1.41	0.709412
Family size	1.22	0.822237
Ln laggedPSesame	1.19	0.842128
Mean VIF	4.59	

Appendix table 3.Conversion factors used to estimate Tropical Livestock Unit equivalents

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

Source: Storck, *et al.* (1991 as cited in Arega and Rashid, 2005).

Appendix table 3.Conversion factor of man equivalent and adult equivalent

Age group (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	1.00	0.8	1.0	0.75
>50	0.7	0.5	1.0	0.75

Source: Storck, et al. 1991

Appendix table 1 Multicollinearity test for explanatory variables efficiency

Variables	VIF	1/VIF
Age square	17.98	0.055617
Age	15.06	0.066401
TLU	10.02	0.0998
Farm visit	9.14	0.109409
Education	4.56	0.217865
Extension	2.99	0.334448
Off/non farm income	2.67	0.374532
Training	2.51	0.398406
Ln credit	1.88	0.531915
Sex	1.75	0.571429
Farm size of other	1.22	0.819672
Family size	1.19	0.840336
Mean VIF	5.92	

Questionnaire

Name of enumerator_____

Date of interview_____

Demo_____

Interview schedule for sorghum, production and Marketing

I. General information

A. Name of the respondent _____ phone number _____

B. Age of respondent _____

C. Head of house hold sex _____ (1=Male 2= Female) and age house hold head_____

D. Tabiya_____

E. Distance Tabiya to Wereda _____ in km_____ in hour on foot

F. Farming experiences _____ years

G. Experience in sorghum farming _____ years

II. Socio-demographics

1. Education level house hold head (years of schooling) put grade_____

A) Illiterate B) Able to read and write C) Primary School D) Secondary school E) Higher education

2. Family sizes (permanently living)? _____ Male_____ Female _____

3. Marital status of household head

A= Married B = Single C = Divorced D = Widowed

4. Had you/ household head participate in any civil association/s? _____ 1) yes 2) no

5. What were the associations that the household head participated if your answer for # 4 is yes?

1= Farmers association 2 = Youth association 3= Edir 4 = Women association

5= Cooperatives 6 = Traders association 7= other, specify _____

6. When was you become a member of the association/s and what was your position?

No	Association	Year of membership	For how many years you are member ship	No of family members	Position of hhd
1					
2					
3					
4					

Use in association 1= Farmers association 2 = Youth association 3= Edir 4 = Women association 5= Cooperatives 6 = Traders association

7. Had you obtain any additional knowledge on agricultural production because of being member of the explained association? _____ 1) yes 2) no

8. What were the advantages you obtain from being member of the association if your answer for # 7 is yes? _____

9. What were the limitation that restrict to obtain additional knowledge if your answer for # 7 is no? _____

10. Total family members _____ female =_____, male =_____

11. Number of active and non-active household members

Activity	Sex	Age	Active family members			non-active family members
			No Full time	Part of time		
				No	Day/week	
On farm	Male	0-14				
	Female					
	Male	15-64				
	Female					
	Male	65 & above				
	Female					
Off farm	Male	0-14				
	Female					
	Male	15-64				
	Female					
	Male	65 & above				
	Female					

Hint: Active refers to the members able to work on farm activity

12. Did you face labour shortage in sorghum production from family in 2008/09 E.C? 1) yes 2) no

13. In which kind of sorghum production activity was the family labor shortage you face? _____

1) Land preparation 2) Ploughing and sowing 3) Hand weeding 4) weeding chemical

5) Harvesting 6) Threshing and cleaning 7) Marketing 8) Others (specify) _____

14. Did there any family members who are engaged in off farm activities? ____ 1) yes 2) no

15. If your answer is yes in # 14, how many of your family members are engaged in off farm activities? Male_____ female_____ total _____ members

16. How much Ethiopian birr you obtained in average from non farm income per year? _____

17. What are the main sources of off farm income?

s/no	Sources off farm income	Number of people engaged	Number of days worked in month	Income per working day	Income per month	Total annual income in average
1	Wage					
2	Selling local drink					
3	Petty trading					
4	Selling fire wood					
5	Handicraft					
6	Herding					
7	Renting tractor					
8	Selling livestock					
9	Remittances					
10	Renting of class					
11	Store, house or office keeper					
12	Others					

III. Land holding

1. Land ownership

1. Total farm size holding _____hectare or _____ hours

2. Total farm cultivated _____ hectare or _____hours

3. Own farm cultivated _____ hectare or _____ hours

4. Rented in farm cultivated _____ hectare or _____hours

5. Rented out farm holding _____ hectare or _____ hours

6. Shared in crop farm cultivated _____ hectare_____ hours

7. Shared out crop farm cultivated _____ hectare or _____ hours

8. Fallow farm land holding in _____ hectare or _____ hours

2. How did you allocated your land in the production year of 2008/09 E.C

No.	**Type of crop**	**Total hectare**	**Own land Size**	**Rented in Size**	**Renting price per hectare**	**Shared in Size**	**Shared out Size**	**Shared system**	**Total quintal produced 2008/09 E.C**	Main purpose of production 1=For home consumption 2= For sale 3= For both	Amount of allocation		
											Sold qt	Consumed qt	Seed qt
1	Sorghum												
2	Sesame												
3	Greengram												
4	Cotton												
5	Maize												
6	Other												

3. Put amount yield produced under this farm plots

S/no	Type of crop	Own farm	Rented farm	Shared in	Shared out
1	Sorghum				
2	Sesame				
3	Greengram				
4	Cotton				
5	Maize				
6	Other				

4. If you rented out land, why was that? _____

5. If you shared out land, why was that? _____

6. In how many sites were located your sorghum farm? _____

7. How far is the average distance among the sites of sorghum? The nearest _____ hr _____Km; and the farthest/ distant _____ hr _____Km

8. Draw the sorghum farm plots and put the time how much it took by foot each plot far away from home and among the plots

9. How many times you visit your farm in 2008/9 E.C production season fill the following according its visit?

No	Activities	1=Yes 2= No	Its frequencies	If no why
1	Land preparation cleaning			
2	Plowing			
3	Sowing (fertilizer + seed)			
4	Weeding			
5	Diseases and pests			
6	Harvesting			
7	Drying panicles			
8	Threshing			
9	Transportation			
10	Other specify			

IV. Improved seed application and Soil fertility status with its improvement

1. What was the fertility status of your sorghum farm? 1) Very low 2) low 3) moderate

4) High 5) Very high

2. Did you apply chemical fertilizer on your sorghum farm? 1= Yes 2= No

3. If your response for #2 is yes, fill the following table

Type of fertilizer	Total fertilizer purchased	Price per Qt	Rate of application (Qt/ha)	Time of application 1= At the time of planting 2= At the time 1st weeding 3= At the time 2nd weeding 4=At the time 3rd weeding 5= Other (specify)	Methods of application 1= broad casting by hand 2= use machinery 3= other (specify)
1. UREA					
2. DAP					
3. NPS					
4. Others					

4. If you did not apply chemical fertilizer on your sorghum, why? **NB** if not as recommendation ask?

s/no	Reasons	1= Yes 2= No	Rank
1	High cost of fertilizer		
2	High fertility status of the soil		
3	Lack of knowledge about the importance of fertilizers		
4	Shortage of fertilizers in the area		
5	Application of fertilizer is not good in the area?		
6	Absence of credit facilities		
7	Lack of fertilizer type I need		
8	Lack of knowledge application of fertilizer		
9	Sorghum was not need fertilizer		
	Others (specify)		

5. Do you use organic fertilizer on sorghum field? ____ 1) Yes 2) No NB if the answer is no skip to question number 10

6. If your response for # 5 is 1, what kind of organic fertilizer did you use? _____

1) Animal waste 2) Compost 3) Green manure

Type of Organic fertilizer	**Total Organic fertilizer in qt**	**Total Transportation cost per qt**	**Purchasing Price per qt**	**Preparation price per Qt**	**Rate of application Qt/ha**	Time of application 1= land preparation 2= At the time of planting 3= At the time 1st weeding 4= At the time 2nd weeding 5=At the time 3rd weeding 6= Other (specify)	Methods of application 1= broad casting by hand 2= use machinery 3= other (specify)
compose							
animal waste							
Green manure							
Others							

7. How much labour do you use to apply organic fertilizer?
A) A number of own labour used in applying organic fertilizer? _____
B) A number of days own labour worked? _____
C) A number of hired labours used in applying organic fertilizer? _____
D) A number of days hired labour worked? _____
E) The average wage per day for application of organic fertilizer? _____

8. How much expenses had you spent to apply the organic fertilizer? _____ Birr
9. How much expenses had you spent to prepare organic fertilizer? _____ Birr
10. If you are not using organic fertilizer, why?
    1) It is bulky to transport? 1=Yes 2= No
    2) I do not have animals to prepare it? 1= Yes 2= No
    3) Lack of awareness importance of organic fertilizer? 1= Yes 2= No
    4) It is not appropriate compared to the farm size? 1= Yes 2= No
    5) Its application is difficult compared with inorganic fertilizer? 1= Yes 2= No
    6) It is consume more time to prepared? 1= Yes 2= No
    7) Others specify

11. Did you practice crop rotation on your sorghum filed? 1= Yes 2= No

12. If your answer is yes in #11 in how many years had you apply crop rotation?
13. With what crop had you rotate your sorghum? _____, _____, _____
14. If you did not apply crop rotation on your sorghum farm what was the reason?
_____

_____

14. Sources and types of seed/varieties used for sorghum planting

No	Name of sorghum varieties used 1= Gobey 2= Berhan 3=Wedi akre 4=wedi arebae 5= Deber 6= Tewzale 7= Korkora 8= Others (specify)	Improved 1= Yes 2= No	Seed quality 1 excellent 2 good 3 medium 4 poor	Source: 1= Research office 2= BoARD 3= NGO 4= Local market 5=Cooperatives 6= Other farmers 7= Traders 8= Own 9= Others (specify)	Rank varieties in market demand
1.					
2.					
3.					
4.					
5.					
6.					
	other (specify)				

15. If you do not apply Sorghum improved variety why it is?
    a) Lack of improved varieties? 1= Yes 2= No
    b) Lack of awareness about improved sorghum varieties? 1= Yes 2= No
    c) Absence of multiplying seed enterprise?1= Yes 2= No
    d) High cost of improved seed as compared to local seed? 1= Yes 2= No
    e) Did you believe local seed is better than the improved seed in production? 1= Yes 2= No
    f) Local seed was have better market demand than the improved seed? 1= Yes 2= No
    g) Others (specify)

V. Livestock resources and income obtained

1. Did you have income obtained from selling of livestock and their products? __ 1) yes 2) no

2. How much income in average had you obtain from selling of livestock products in a year or 2008/09 E.C production season? _____ Birr

3. For what purpose did you use income obtained in a year from livestock? _____

s/no	Purpose had use income obtained from livestock	1= Yes 2= No	Average share amount
1	For buying food expenses		
2	For crop/sorghum production		
3	For repayment of credit		
4	For health expenses		
5	For educational expenses		
6	For clothes expenses		
7			

4. What types of livestock had you own and sold in 2008/09 E.C production season? _____

Herd type	Breed type	Total animal holding	No soled	Unit price (birr)	Expenses in birr	Net revenue obtained (birr)
Oxen						
Cow						
Heifer						
Bull						
Calve						
Adult Sheep						
Young sheep						
Adult Goats						
Young Goats						
Camel						
Donkey						
Poultry						
Total						

$Hint_1$: if oxen, Donkey and /or Camel was used for ploughing power these should be deducted

$Hint_2$: For breed type 1= Arado 2= Begayte3=Exotic

VI. Credit and Extension service supports in production and marketing

1. Credit support service and budget required

A) What was the total finance required? _____

B) How much of your own money did you use for financing the production?_____

C).Did you get credit for 2008/9 E.C production season? 1= Yes 2= No

D) If your response is yes, how many times you get credit in one season? _____

E) What was the total amount of money you borrowed? _____

F) Did you miss credit that you needed for the production season? 1= Yes 2= No

G) If your response is yes, how much did you miss? _____

H) Did try to fill full the missed amount of budget? 1= Yes 2= No

I) If your response is yes, how did you fill the missed budget?

_____

2. Source of credit

A) Fill the following table the loan taken for the 2008/9 EC production season?

No	Loan provider	Loan amount	Loan application date	Loan receiving date	Agreed loan repayment date	Actual loan repayment date	Preferred repayment date	Total repayment(birr)	Total repayment kind in (quintal)	Price per quintal at
1										
2										
3										
4										
5										

Use 1= Banks 2=Friend 3= Relatives 4=Informal money lenders (IMF) 5= Micro finance 6=Cooperatives 7= SACCO (saving and credit cooperatives) 8= others (specify_____

B) Fill the following table from which loan providers, the respondent could not get a loan the reason for that?

	Did get loan from (1=Yes 2=No)	If No did you try to get loan from (1=Yes 2=No)	What is the reason you did not get a loan	Other reason
Bank				
Friend				
Relative				
IMF				
Micro finance				
Cooperatives				
SACCO				
Other				

Use 1= No matching collateral; 2= Lack of trust in group collateral; 3= Credit provider is not available in the area; 4=Bad history of credit repayment; 5=Too high interest rate; 6=Volume of credit is too limited; 7= The loan released too late; 8= Because of you get credit from other source and 9=other specify ____

C) Please rank from (1to 6), at what moment you were need of credit the most in past production season?

Priority	**Activities**	**Date**
1		
2		
3		
4		
5		
6		

Use 1=land preparation; 2= purchasing fertilizer; 3= Sowing (fertilizer and seed); 4= Weeding; 5= chemical purchasing and application; 6= Harvesting; 7= Threshing; 8= Transportation 9= Storage and 10= marketing

VII. Extension support service

A) Did you get extension services in 2008/9 E.C production season? 1= Yes 2= No

B) If your response is yes, how many times did the development agent visits you? _____

C) How the frequent was the visit?

1=Per week 2= Per two week 3=Per three week 4= Per month 5= None regular

D) If you get extension services in 2008/9 E.C production season fill the following according its visit?

No	Activities	1=Yes 2= No	Its frequencies	If no why
1	Land preparation			
2	Purchasing fertilizer			
3	Sowing (fertilizer + seed)			
4	Weeding			
5	Diseases and pests			
6	Harvesting			
7	Threshing			
8	Transportation			
9	Storing			
10	Selling			
11	Training			
12	Others (specify)			

E) Amount of produced sorghum varieties yield, biomass and cultivated land size

No	Varity of sorghum	Hectare	Yield of grain product produced	By product of Panicle	Biomass (steam)
1					
2					
3					

VIII. Marketing Practices

1. Did you sell your sorghum grain product of 2008/09 EC production season? 1= Yes 2= No
2. If your response is yes, when and how do you sell your product or sorghum?

Bach		Sorghum varieties		
Bach 1(selling date)				
	Amount of quintal you sell			
	Birr per quintal			
	For whom did you sell			
	Did you use own transport to market 1= Yes 2= No			
	Total return			
Bach 2(selling date)				
	Amount of quintal you sell			
	Birr per quintal			
	For whom did you sell			
	Did you use own transport to market 1= Yes 2= No			
	Total return			
Bach 3(selling date)				
	Amount of quintal you sell			
	Birr per quintal			
	For whom did you sell			
	Did you use own transport to market 1= Yes 2= No			
	Total return			
Bach 4(selling date)				
	Amount of quintal you sell			
	Birr per quintal			
	For whom did you sell			
	Did you use own transport to market 1= Yes 2= No			
	Total return			
Bach 5(selling date)				
	Amount byproduct of panicle sell in quintal			
	Average price per quintal of by product			
	Amount biomass (steam) per camel			
	Average price biomass (steam) per camel			
	Amount of biomass (steam) cart			
	Average price per cart			
	Amount contract biomass (steam)			
	Average price of contract sell			
	Total return			
Total				

Use 1= Local farmers 2= local collectors 3= Wholesaler 4= Retailer 5= Cooperatives 6= Union
7=Others (specify)

3. Who sets price?

1= Producers 2= Buyer 3= Both producer and seller 4=Others (specify)

4. Where did you sell your sorghum?

1) At farm gate 2) At Humera 3) At central market 4) At the nearest market
5) At the warehouse 6) Others (specify) ___

5. The average distance of market place from resident, the farthest in kilometer _____ and _____in hour also the nearest market distance in kilometer_____ and_____ in hour

6. From whom/where did you get market information?

1. Extension agents 1= Yes 2= No
2. Bureau of agriculture and rural development 1= Yes 2= No
3. TV or radio 1= Yes 2= No
4. Neighborhood producers/farmers 1= Yes 2= No
5. Own market survey 1= Yes 2= No
6. Family 1= Yes 2= No
7. Friend 1= Yes 2= No
8. Relatives 1= Yes 2= No

Others (specify) _____

7. How much the average price of sorghum of 2007/8 E.C production season and list the varieties?

1= Gobey _____, _____, _____, 2= Deber _____, _____, _____,
3=Wedi akre_____, _____, _____,4=wedi arebae _____, _____, _____,
5= Berhan _____, _____, _____, 6= Tewzale _____, _____, _____,

7= Korkora _____, _____, _____, others (specify) _____, _____, _____

8. How much an average price of sesame in the 2007/08 production season _____, _____, _____,

9. What is your opinion on marketing of sorghum and rank in there priority?

s.no	Limitation on sorghum marketing	1= Yes 2= No	Rank
1	Lack of accurate and timely market information		
2	Absence of centralized sorghum marketing system		
3	Absence of primary/union cooperatives engaged in marketing		
4	Lack of contractual arrangements between producers and buyers		

5	Inappropriate and illegal interference of brokers		
6	High degree of market price fluctuation		
7	Lack of market infrastructures (road)		
8	Other (specify)		
9			

IX. Production cost

No	Activities		Things used	Amount	Varity	cost
1	Land cleaning		Material purchased			
			Unit cost for purchased material			
			Amount of own labour used			
			Number of day own labour worked			
			Hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			
			Total cost			
2	Seed		Own seed used in kilo gram			
			Purchased seed used in kilo gram			
			Average price in kilo gram			
			Total amount of seed used			
			Total cost			
3	ploughing	ploughing^{1st}	Material purchased			
			Unit cost for purchased material			
			Own tractor used time in hour			
			Rented tractor used time in hour			
			Price per hour rented tractor			
			Total time used			
			Total cost			
		ploughing^{2nd}	Material purchased			
			Unit cost for purchased material			
			Own tractor used time in hour			
			Rented tractor used time in hour			
			Price per hour of rented tractor			
			Total time used			
			Total cost			
	Ploughing + sowing		Material purchased			
			Unit cost of purchased material			
			Own tractor used time in hour			
			Hired tractor used time in hour			
			Price per hour of rented tractor			
			Own labour used			
			Number of day worked			
			Hired labour used			
			Number of day worked			
			Average wage per a day for hired labour			
			Total labour used			
			Total cost			

no	Activities		Things used	Sorghum varieties		
4	Seed shallow		Purchased material			
			Unit cost for purchased material			
			Number of own paired oxen used			
			Number of days used the peered oxen			
			Number of rented paired oxen used			
			Number of days used the rented paired oxen			
			Rented average price paired oxen per a day			
			Number of own camel used			
			Number of days own camel used			
			Number of rented camel used			
			Number of days rented camel used			
			Average price of rented camel per a day			
			Amount of own labour used			
			Number of day own labour worked			
			Hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Total labour used			
			Total cost			
5	fertilizer		Amount of DAP purchased			
			Average price of DAP per quintal			
			Amount of urea purchased			
			Average price of urea per quintal			
			Transportation cost per quintal to store			
			Amount of own labour used in loading un loading			
			Number hired labour used in loading unloading			
			Price of loading and unloading per quintal			
	Fertilizer application	1st	Material purchased			
			Unit cost of purchased material			
			Amount of urea transported to farm			
			Amount of DAP transported to farm			
			Transportation cost per quintal to farm			
			Amount of own labour used in loading un loading			
			Number hired labour used in loading unloading			
			Average price of loading and unloading per quintal			
			Number of own labour used in fertilizer sowing			
			Number of days own labour work in fertilizer sowing			
			Number of hired labour used in fertilizer sowing			
			Number of days hired labour work in fertilizer sowing			
			Average price of fertilizer application			
			Total labour used			
			Total cost of 1st fertilizer application			

no	Activities		Things used	Sorghum varieties		
	Fertilizer application	2nd	Material purchased			
			Unit cost of purchased material			
			Amount of urea transported to farm			
			Amount of DAP transported to farm			
			Transportation cost per quintal to farm			
			Price of loading and unloading per quintal			
			Amount of own labour used in loading un loading			
			Number hired labour used in loading unloading			
			Number of own labour used in fertilizer sowing			
			Number of days own labour work in fertilizer sowing			
			Number of hired labour used in fertilizer sowing			
			Number of days hired labour work in fertilizer sowing			
			Average price of fertilizer application			
			Total labour used			
			Total cost of 2nd fertilizer application			
6	Hand weeding	1st	Material purchased			
			Unit cost for purchased material			
			Amount of own labour used			
			Number of day own labour worked			
			Number hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			
			Total cost			
		2nd	Material purchased			
			Unit cost for purchased material			
			Amount of own labour used			
			Number of day own labour worked			
			Number hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			
			Total cost			

no	Activities		Things used	Sorghum varieties		
	Hand weeding	3rd	Material purchased			
			Unit cost for purchased material			
			Amount of own labour used			
			Number of day own labour worked			
			Number hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			
			Total cost			
7	Chemical application for weeding	1st	Material purchased			
			Unit cost for purchased material			
			Amount of chemical used in liter			
			Unit cost per liter			
			Amount of own spry used			
			Number of days used own spry			
			Amount renting spray used			
			Number of days used rented spry			
			Average price of renting spray per day			
			Amount of own labour used			
			Number of day own labour worked			
			Hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			
			Total cost			

no	Activities		Things used	Sorghum varieties		
	Chemical application for weeding	2nd	Material purchased			
			Unit cost for purchased material			
			Amount of chemical used in liter			
			Unit cost per liter			
			Amount of own spry used			
			Number of days used own spry			
			Amount renting spray used			
			Number of days used rented spry			
			Average price of renting spray per day			
			Amount of own labour used			
			Number of day own labour worked			
			Number of hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			
			Total cost			
		3rd	Material purchased			
			Unit cost for purchased material			
			Amount of chemical used in liter			
			Unit cost per liter			
			Amount of own spry used			
			Number of days used own spry			
			Amount renting spray used			
			Number of days used rented spry			
			Average price of renting spray per day			
			Amount of own labour used			
			Number of day own labour worked			
			Number of hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			

No	Activities		Things used	Sorghum varieties		
8	Chemical application for pest and diseases	1st	Material purchased			
			Unit cost for purchased material			
			Amount of chemical used in liter			
			Unit cost per liter			
			Amount of own spry used			
			Number of days used own spry			
			Amount renting spray used			
			Number of days used rented spry			
			Average price of renting spray per day			
			Amount of own labour used			
			Number of day own labour worked			
			Number of hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			
			Total cost			
		2nd	Material purchased			
			Unit cost for purchased material			
			Amount of chemical used in liter			
			Unit cost per liter			
			Amount of own spry used			
			Number of days used own spry			
			Amount renting spray used			
			Number of days used rented spry			
			Average price of renting spray per day			
			Amount of own labour used			
			Number of day own labour worked			
			Number of hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			
			Total cost			

no	Activities		Things used	Sorghum varieties		
	Chemical application for pest and diseases	3rd	Material purchased			
			Unit cost for purchased material			
			Amount of chemical used in liter			
			Unit cost per liter			
			Number of own spry used			
			Number of days used own spry			
			Number renting spray used			
			Number of days used rented spry			
			Average price of renting spray per day			
			Number of own labour used			
			Number of day own labour worked			
			Number of hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			
			Total cost			
9	Panicle Harvesting		Material purchased			
			Unit cost for purchased material			
			Number of own labour used			
			Number of days own labour worked			
			Number of hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			
			Total cost			
10	Biomass harvesting		Material purchased			
			Unit cost for purchased material			
			Number of own labour used			
			Number of days own labour worked			
			Number of hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			
			Total cost			

no	Activities		Things used	Sorghum varieties		
11	Threshing	Preparing threshing area	Material purchased			
			Unit cost for purchased material			
			Number of own labour used			
			Number of days own labour worked			
			Number of hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Total labour used			
			Total cost			
		Cattle	Material purchased			
			Unit cost for purchased material			
			Number own cattle used			
			Number of days own cattle worked			
			Number of rented cattle used			
			Number of days rented cattle worked			
			Average rented price of cattle for threshing per day			
			Number of own labour used			
			Number of days own labour worked			
			Number of hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Contract amount of hired labors			
			Number of day contract hired labour worked			
			Cost of contractual agreement			
			Amount threshed quintal of sorghum			
			Total labour used			
			Total cost			
		Machine	Material purchased			
			Unit cost for purchased material			
			Number of own labour used			
			Number of days own labour worked			
			Number of hired labour used			
			Number of day hired labour worked			
			Average wage per a day			
			Number of threshed quintal of sorghum by own machine			
			Number of threshed quintal of sorghum by rented machine			
			Average price of threshing per quintal			
			Total labour used			
			Contractual number of hired labour			
			Number of days contractual labour worked			
			Cost of contractual agreement			
			Total cost			

no	Activities	Things used	Sorghum varieties		
12	Sack and roping cost	Material purchased			
		Unit cost for purchased material			
		Number of own sack used			
		Number of purchased sack used			
		Average price of sack			
		Number of own rope used			
		Number of purchased rope used			
		Average price rope			
		Total cost			
13	Loading unloading from farm to store	Number of own labour used in loading un loading			
		Number of quintal loading un loading by own labour			
		Number hired labour used in loading unloading			
		Number of quintal loading un loading by hired labour			
		Average price of loading and unloading per quintal			
		Total labour used			
		Total cost			
14	Transportation from farm to store	Number of quintal transported by own transporter			
		Number of quintal transported by rented transporter			
		Average price of transportation per quintal			
		Total labour used			
		Total cost			
15	Loading unloading from store to market	Number of own labour used in loading un loading			
		Number of quintal loading un loading by own labour			
		Number hired labour used in loading unloading			
		Number of quintal loading un loading by hired labour			
		Average price of loading and unloading per quintal			
		Total labour used			
		Total cost			
16	Transportation from store to market	Number of quintal transported by own transporter			
		Number of quintal transported by rented transporter			
		Average price of transportation per quintal			
		Total labour used			
		Total cost			
17	Store	Number of quintal stored in own store			
		Number of month stored in own store			
		Number of quintal stored in rented store			
		Number of month stored in rented store			
		Average monthly price of rented store per quintal			
		Total cost			

no	Activities	Things used	Sorghum varieties		
18	For food and water costs	Amount of purchased material			
		Unit price of purchased material			
		Amount of flour in quintal			
		Average price of grain flour per quintal			
		Amount of flour pepper in kilogram			
		Average price of flour of pepper per kilogram			
		Amount of salt used in kilogram			
		Average price of salt per kilogram			
		Amount of *shiro* used in kilogram			
		Average price of *shiro* per kilogram			
		Amount of bean used in kilogram			
		Average price of bean in kilogram			
		Amount of water used in cart			
		Average price of water per cart			
		Transportation cost for food items as whole			
		Total cost			
19	Cost of tractor	Diver cost			
		Supporter cost			
		Services cost			
		Maintenance cost			
		Fuel cost			
		Lubricant cost			
20	Additional costs	Farm manager cost (*coberari*)			
		Teller cost			
		Auditing cost			
		Land taxation cost			
		Income taxation cost			
		Other cost			

Thanks for all things