STATISTICAL ANALYSIS OF DETERMINANTS OF CROP PRODUCTIVITY AND HOUSEHOLD POVERTY: THE CASE OF MENZ KEYA GEBRIEL DISTRICT, ETHIOPIA

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DEDICATION

I dedicate this Thesis manuscript to my mother Aselefech Tesfaye and my brothers Geletaw, Talelgn and Fiseha for upbringing me with love and for their sacrifice in the success of my life.

BIOGRAPHICAL SKETCH

The author, Cherie Kassa was born in March, 1987 in Amhara region North Shewa Zone, Menz Keya Gebriel District, Kolako Kebele.

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LIST OF ACRONYEMS AND ABBREVIATIONS

ADLI	Agricultural Development Led Industrialization
AE	Allocative Efficiency
CDF	Cumulative Distribution Function
DEA	Data Envelopment Analysis
DF	Degree of Freedom
EE	Economic Efficiency
ETB	Ethiopia Birr
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
HDI	Human Development Index
HH	Households
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
LDC	Least Developed Countries
LR	Likelihood Ratio
MDG	Millennium Development Goal
MLE	Maximum likelihood estimation
MoFED	Ministry of Finance and Economic Development Ethiopian
OLS	Ordinary Least Square
SFM	Stochastic Frontier Model
SPF	Stochastic Production Frontier
SPSS	Statistical Package for Social Sciences
TE	Technical Efficiency
TLU	Tropical Livestock Unit
UNDP	United Nations Development Program
VIF	Variance Inflation Factor
WB	World Bank

TABLE OF CONTENTS

STATEMENT OF THE AUTHOR	**iii**
DEDICATION	**iv**
BIOGRAPHICAL SKETCH	**v**
ACKNOWLEDGEMENTS	**vi**
LIST OF ACRONYEMS AND ABBREVIATIONS	**vii**
TABLE OF CONTENTS	**viii**
LIST OF TABLES	**x**
LIST OF TABLES IN THE APPENDIX	**xi**
LIST OF FIGURES IN THE APPENDIX	**xii**
ABSTRACT	**xiii**
1. INTRODUCTION	**1**
1.1. Background of the Study	1
1.2. Statement of the Problem	4
1.3. Objectives of the Study	7
1.4. Significance of the Study	7
1.5. Scope and Limitation of the Study	8
2. LITRATURE REVIEW	**9**
2.1. Basic Concepts for Productivity, Efficiency and Poverty	9
2.1.1. Measurement of productivity and efficiency	10
2.1.2. The relationship between agricultural productivity and poverty	11
2.2. Analytical Framework for Productivity, Efficiency and Poverty	13
2.2.1. Production Function	13
2.2.2. Productivity and efficiency analysis	13
2.2.2.1. Deterministic frontier model	14
2.2.2.2. Stochastic frontier model	15
2.3. Empirical Literature on Productivity, Efficiency and Poverty	18
3. RESEARCH METHODOLOGY	**26**
3.1. Description of the Study Area	26
3.1.1. Location of the study area	26
3.1.2. Demographic characteristics of the study area	26
3.1.3. Economic activities in the study area	26
3.2. Sample Size Determination and Sampling Techniques	27

TABLE OF CONTENTS (Continued)

3.3. Data Types and Methods of Data Collection 30

3.4. Methods of Data Analysis 30

3.4.1. Stochastic frontier model (SFM) 31

3.4.1.1. Estimation method of the model parameters for SFM 35

3.4.1.2. Goodness of fit for the model 38

3.4.2. Logistic regression model 40

3.4.2.1. Method of estimation for the logistic regression model 43

3.4.2.2. Assessing the goodness of fit for logistic regression model 44

3.5. Definition and Measurement of Variables 46

4. RESULTS AND DISCUSSION 53

4.1. Descriptive Results 53

4.1.1. Demographic and socio-economic characteristics 53

4.1.2. Institutional characteristics 54

4.1.3. Summary statistics for quantitative variables used in the study 56

4.1.4. Summaries of crop yield and rate of main inputs used 58

4.2. Econometrics Model Results 64

4.2.1. Parameter estimation of SFM and inefficiency effect 64

4.2.1.1. Input elasticity and returns-to- scale 69

4.2.1.2. Estimation of determinants of inefficiency 73

4.2.2. Logistic regression model for poverty analysis 77

4.2.2.1. Estimation of model parameters 77

4.2.2.2. Assessing the goodness of fit for the model 78

4.2.2.3. Interpretation of the coefficients of logistic regression model 80

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS 82

5.1. Summary and Conclusion 82

5.2. Recommendations 85

6. REFERENCES 87

7. APPENDICES 97

Appendix 1: Appendix Tables 97

Appendix 2: Appendix Figures 100

Appendix 3: Survey Questionnaire 103

LIST OF TABLES

Table	Page
1: Summaries of demographic characteristics of the households with poverty status	54
2: Summaries of categorical variable related with poverty status of the household	55
3: Descriptive statistics for production, income and related variables (n=207)	58
4: Descriptive Statistics of variables for teff crop production (n=204)	59
5: Summary Statistics of variables for wheat crop production (n=187)	60
6: Descriptive Statistics of variables for bean crop production (n=172)	61
7: Summary Statistics of variables for barley crop production (n=115)	61
8: Descriptive Statistics of variables for sorgum crop production (n=80)	62
9: Summaries of mean production and productivity of the five crops and input variables	63
10: Stochastic frontier model results for productivity of five major crops	64
11: Determinants of technical inefficiency score for the productivity of five crops	65
12: log likelihood test for the existence of inefficiency component for each crop	66
13: Log likelihood ratio tests about the goodness of the inefficiency effect model	67
14: Goodness of fit test for the stochastic frontier model for each crop	68
15: Summary of efficiency scores by crop type	72
16: Estimation results of the logistic regression model for poverty analysis	78

LIST OF TABLES IN THE APPENDIX

Appendix Table Page

1. Conversion factors to compute tropical livestock unit (TLU) 97

2. Variance Inflation Factor (VIF) for input and inefficiency variables. 97

3: Contingency coefficient of variables in inefficiency effect for *teff* productivity 97

4: Contingency coefficient of variables in inefficiency effect for wheat productivity 98

5: Contingency coefficient of variables in inefficiency effect for bean productivity 98

6: Contingency coefficient of variables in inefficiency effect for barley productivity 98

7: Contingency coefficient of variables in inefficiency effect for sorgum productivity 98

8: Contingency coefficient of variables in logistic regression model of poverty analysis 99

9: Goodness of fit test of the logistic regression model 99

10: Hosmer-Lemeshow, goodness-of-fit test 99

11: Analog of Cook's influence statistics 99

LIST OF FIGURES IN THE APPENDIX

Appendix Figure Page

1: Histogram of the residual of SFM for *teff* productivity 100

2: Histogram of the residual of SFM for wheat productivity 100

3: Histogram of the residual of SFM for bean productivity 101

4: Histogram of the residual of SFM for barley productivity 101

5: Histogram of the residual of SFM for sorgum productivity 102

Statistical Analysis of Determinants of Crop Productivity and Household poverty: The case of Menz Keya Gebriel District, Ethiopia

ABSTRACT

In Ethiopia, agricultural productivity in general and crop productivity in particular is low and has been a critical problem. The study was intended to assess determinants of crop productivity, TE and household poverty in Menz Keya Gebriel district of North Shewa Zone, Ethiopia. The primary data for this study were collected from 207 randomly selected sample households from the district using stratified random sampling based on agro ecology. The analysis basically employed both descriptive and econometric methods. Stochastic frontier and Logistic regression model were used for productivity and poverty analysis, respectively. Cobb- Douglas stochastic frontier model was used to estimate the elasticities of production frontier and inefficiency effect simultaneously by using MLE method for five crops separately. The results of productivity analysis shown that seed, fertilizer, oxen-pair days and labor force affect teff and wheat productivity positively. The inputs (seed, oxen-pair days, labor force) affect bean productivity positively. Fertilizer, oxen-pair days and labor force affect barley productivity positively. Oxen-pair days and labor force has positive effect on sorgum productivity. In most cases, fertilizer, oxen- pair days and labor force affect crop productivity positively. Moreover, the results of efficiency analysis shows that the mean level of technical efficiency for teff, wheat, bean, barley and sorgum crop productivity was 91.11, 88.8, 83.4, 85.6, and 88.2 percent, respectively. The results of the inefficiency analysis shows that sex, education level and age of household head, family size, health status, land quality, number of extension contact, credit, agro-chemical and improved seed were the determinants of TE of crop productivity. The study also used logistic regression model for the analysis of determinants of household poverty. The determinants of household poverty were sex of the household head, crop productivity as market value (birr/ha), place of residence, dependency ratio, livestock holding in TLU, non or off-farm activity, non-labor income, and irrigation. Among these significant variables, except place of residence and dependency ratio, all play significance role in poverty reduction. It is suggested that further study conducted on the dynamics of total factor productivity and multi-dimensional poverty of the household in the area.

Key words: Crop productivity, Technical efficiency, Cobb-Douglas stochastic frontier, Poverty, Logistic regression.

1. INTRODUCTION

1.1. Background of the Study

The volume of agricultural production and productivity explains the variation in the standard of living around the world. Especially in developing countries, where the vast majority of the populations live in the rural area, the future of the population depends on the countries' ability to develop rural areas. In these rural areas, agriculture is the main means of livelihood. It is also the back bone of national economies, the main source of income, and by far the most important source of employment (WB, 2008; Dethier and Effenberger, 2012; UNDP, 2013).

Developing countries are characterized by low level of standard of living, low productivity, high and rising population growth, high rate of unemployment and significant dependence on agricultural product for the growth of the overall economy. Agriculture has long been, and continues to be, the mainstay of rural economies in sub-Saharan Africa and throughout the developing world. More than half of the population gets their food from own-production. Agriculture output is also used as an input for industries so as to stimulate the growth of industrialization. Improving agricultural productivity thus has contributed to income growth UNDP (2007).

In sub-Saharan Africa (excluding South Africa) 60-80% of the population is employed in agriculture, producing 30-40% of GDP (WB, 2007; Staatz and Dembele, 2008). The performance of economies in many sub-Saharan African countries is closely related to productivity growth in the agricultural sector which implies that overall economic growth and poverty reduction efforts in the region are greatly determined by the performance of this sector (Mwambu and Thorbecke, 2004; Christiaensen and Demery, 2007; Staatz and Dembele, 2007; Diao *et al*., 2010).

Ethiopia is one of the Sub-Saharan African countries located in East Africa. Ethiopia's economy is predominantly agrarian where agriculture plays a key role in the social and economic development. It is one of the largest countries in Africa both in terms of population and land area with diverse demographic, socio-cultural and agro-ecological features. It has more than 80 ethnic groups and about 1.12 million square kilometers of land area MoARD (2008). The country's total population is about 90 million (government of Ethiopia latest estimate is 85.5 million; UN estimate is 94.1 million), and population growth rate of 2.6% WB (2013).

Among the population of the country, most live in rural part of the country and some of them in urban areas. For those who live in rural parts of Ethiopia, the source of livelihood of the household is agriculture and agriculture related activities. So living standard and poverty status of the household depend on agricultural productivity. Approximately 85% of Ethiopians derive their livelihoods directly from agriculture, which contributes over 70 % of national foreign exchange, absorbs 80% of labor force, and contributes 43% of GDP UNDP (2013).

Agricultural production in Ethiopia is characterized by subsistence orientation, low productivity, low level of technology and inputs, lack of infrastructures and market institutions, and extremely vulnerable to rainfall variability. In this country, production and productivity of major crops is low due to the existence of production inefficiency. This is the greatest challenge in the country that has been the prevalence of deep rooted, multidimensional poverty and food insecurity. Because of being structurally food deficit for many decades, Ethiopia has been persistently exposed to food aid dependency to feed millions of its people (MOFED 2008; Mohammed and Kidanemariam, 2014; Wassie, 2014).

The Government of Ethiopia has made significant efforts in terms of public investments and new agricultural technologies to speed up agricultural productivity as a means of accelerating the economic transformation MOFED (2012). The Government is giving greater attention to agricultural productivity by applying the strategy of Agricultural Development Led Industrialization (ADLI). The government, through its National Development Plan, underpins the importance of boosting agricultural product and productivity in order to expand incomes and create sustainable jobs. Agricultural productivity can be boosted through either adopting new technology or efficiency improvement. It may be difficult to adopt new technology to boost productivity due to capital constraint. Hence, working to improve production efficiency is best option on hand. Therefore, the question of efficiency in resource allocation in traditional agriculture is crucial. It is widely held that efficiency is at the center of agricultural production. This is because the scope of agricultural production can be expanded and sustained by farmers through efficient use of resources Hailu *et al.* (2005). Efficiency has remained an important subject of empirical investigation particularly in developing economies where majority of the farmers are resource-poor Umoh (2006). The crucial role of efficiency in increasing agricultural output has been widely recognized by researchers (Hailu *et al.*, 2005; Ghorbani *et al.*, 2009; Ozkan *et al.*, 2009). Because, efficiency of a farm is an indicator to its success in producing as large amount of output as possible given a set of inputs.

Agricultural sector to remain competitive in the market and be profitable, achieving a high level of technical efficiency is of prime importance Ghorbani *et al*. (2009). Achievement of higher productivity levels and sustainable resource utilization in the agricultural sector necessitates smallholder producers to be economically efficient. This ultimately makes smallholder farmers competitive in market-oriented crops production. Furthermore, achieving high level of resource use efficiency hence increase in productivity in smallholder agriculture.

Poverty is generally considered as a situation in which the underprivileged do not have adequate food and shelter, lack access to education and health services, are exposed to violence, and find themselves in a state of unemployment, vulnerability and powerlessness. Poverty is multi dimensional and has to be looked at through a variety of indicators such as levels of income and consumption, social indicators and indicators of vulnerability to risks and socio-political access and participation. The most common approach to the measurement of poverty is based on incomes or consumption levels (WB, 2008; Ayalneh, 2011; Ayele *et al.*, 2013). It is widely understood that an individual is considered poor if income level falls below some minimum level necessary to meet basic needs i.e. poverty line. The nature and level of basic need satisfaction varies along with time and societies and the poverty line to be established should be appropriate to the level of development, societal norms, and values. Poverty has fallen rapidly over the past 40 years, but at different rates around the world. Historically, rates of poverty reduction have been very closely related to agricultural performance particularly to the rate of growth of agricultural productivity. In simple terms, this indicates that the countries that have increased their agricultural productivity have also achieved the greatest reductions in poverty. Poverty is pervasive and widespread in Ethiopia (Bogale *et al*., 2005; Dercon and Christiaensen, 2011; Dercon *et al*., 2012). The government statistics shows that 29.6 percent of the total population of the country lives below the national poverty line. Moreover, poverty is more prevalent in rural (30.4 percent) than urban areas (25.7 percent) MOFED (2012). Other studies also confirm that poverty disproportionately affects people in the rural areas (Ayalneh *et al*., 2005; WB, 2008; IFAD, 2010).

1.2. Statement of the Problem

Ethiopia is an agrarian country. Agriculture is the leading sector as source of income, employment, and foreign exchange. National economic growth is determined by the performance of agriculture. The majorities of Ethiopians live in rural areas and the feature of living depends on agricultural production and productivity. The small-scale farming dominates the overall national economy. But agricultural production and productivity is poor and hence it failed to meet the food demand of the ever-growing population. Yield of cereals has been consistently well below world average and even of least developing countries average yield, indicating poor productivity of the crops in the country FAO (2011). According to FAO (2011) the average cereal yield for the world and least developing countries were 37.08 qt/ha and 20.19 qt/ha, respectively. However, the average cereal yield in Ethiopia was limited to 17.60 qt/ha.

Agriculture in the country is characterized by limited use of improved input, less use of agricultural technology and high dependence on rain. The factors attributing for poor productivity are recurrent droughts, environmental degradation, poor infrastructure in quality and quantity UNDP (2007). For this reason, the Ethiopian government gives more emphasis to the agricultural sector and sustainable economic development that supported by effective agricultural technology intervention like small-scale irrigation as a means of achieving food self-sufficiency MOFED (2010). Agricultural production and productivity can be improved either through increased use of inputs/ improvement in technology or improving the efficiency of farmers given fixed level of inputs and technology. For countries like Ethiopia that have financial problem, the best option to boost production and productivity is by improving technical efficiency of the farmers (Endrias *et al*., 2013; Solomon, 2014 and Wassie, 2014).

The problem of low productivity and technical inefficiency of production is not only limited to crop production but also on the livestock production and over all agricultural production process of rural households. Hence understanding the determinant factors of farmer's present level of crop productivity, production inefficiency as well as poverty was essential to design strategy that improve crop productivity and accelerate the reduction of production inefficiency and poverty. In Ethiopia, technical inefficiency is imposing a problem on improvement of crop productivity and poverty reduction. Studying such a problem helps the country to address the problem. On other hand, many authors emphasized that production inefficiency and poverty varies with time, geographic location, economic and social conditions. The productivity of farmers can be raised by either adoption of improved agricultural technologies or improvement in efficiency of farmers or both. The study conducted by Wassie (2014) shows that the mean level of technical efficiency for major crops production is 63.56% implying that there is a room to boost major crops production by 36.44% in Ethiopia. Another study by Solomon (2014) confirmed that there was inefficiency in the production of teff, wheat, barley, maize and sorgum. High production and productivity are a direct consequence of efficiency in input use and combination given the prevailing technology Ogundari and Ojo, 2008). A study conducted by Endrias *et al*. (2013) also shows a high percentage of technical inefficiency in maize production.

Crop production inefficiency is recognized as a serious problem to sustained and improve crop production in Ethiopia (Alemu *et al.*, 2009; Endrias *et al*., 2013; Essa *et al*., 2012;Wassie, 2012; Solomon, 2014 and Wassie, 2014). An effective economic development strategy and program depends on critically promoting productivity and output growth particularly among smallholder producers to reduce technical inefficiency of production and poverty. To achieve this, a study of farmers' present level of productivity, technical efficiency, and analysis of factors influencing their level of efficiency is necessary. This study analyzes determinants of crop productivity, technical inefficiency of major crops and household poverty in Menz Keya Gebriel district. In general, enough studies specific to district level of the country have not been made, though there are some efforts to examine farmers' present level of production inefficiency and poverty to the respective determinants. To my knowledge no studies published on analysis of the determinants of crop productivity, TE and poverty in Menz Keya Gebriel district. Therefore, this research would contribute to these pressing problems by identifying and analyzing the determinants of crop productivity, technical inefficiency and poverty in this area and to model each crop productivity and inefficiency effect separately as well as household poverty. Many studies identified factors that determine crop productivity, production inefficiency and poverty; however, there were misuse of statistics in most previous studies in the case of descriptive statistics calculation of mean and standard deviation for categorical variables and made conclusion from descriptive statistics results on the effects. Making inferential statistics for the fitting statistical models without checking the assumptions (using average production function without testing existence of inefficiency component), without goodness of fit test for the model and fitting linear regression for categorical dependent variable. To sum up, the objectives of this study are aimed at analyzing determinants of crop productivity, inefficiency and household poverty to overcome the shortcomings outlined above using appropriate statistical methods.

In line with the above evidence, the research/study attempted to come up with possible solutions and recommendations after having clear understanding upon the situation by giving due emphasis to answer the following research questions:

1. What is the responsiveness of yield of crops to the existing level of input?
2. How much does yield of the crop changed for the aggregate change of inputs?
3. What are the main determinants of inefficiency? Is there any room for improvement in the level of efficiency?
4. What are the factors that determine household poverty?

1.3. Objectives of the Study

The main objective of this study is to assess productivity and technical efficiency of major crops production and also identify factors that determine the poverty status of the household in Menz Keya Gebriel district.

The specific objectives of this study are to:

1. Estimate the level of responsiveness (elasticity) of crop productivity with respect to factor inputs and evaluate the return to scale for the production function;
2. Identify factors affecting technical efficiency and determine the level of technical efficiency of crop productivity;
3. Analyze factors associated with household poverty in the district.

1.4. Significance of the Study

It is obvious that agricultural productivity plays a crucial role in the overall development of the country's economy. Therefore, conducting study in this area has a number of significance. Analysis of productivity, technical efficiency and poverty can help policy makers, service providers and community groups assess the need for assistance, judge the effectiveness of the existing programs designed to improve productivity and reduce poverty. This helps the concerned body to give special attention on the identified problems. The significance of this research is, first to generate relevant data on productivity and determinants of technical efficiency for major crops production, as well as the income and poverty status of the household in the study area. Second, it supports the district as well as zonal level planners, policy makers, researchers and development actors in both the governmental and non-governmental organizations working in the area, as well as elsewhere in the country with similar socio-economic, cultural, and physical environment. Finally, taking appropriate measures by the concerned body based on the study result benefit the household particularly in the study district and as well as the country in general. This study also helps to initiate researchers to do further in depth studies on this issue in the district.

1.5. Scope and Limitation of the Study

This study has used 207 randomly selected sample households in Menz Keya Gebriel district of North Shewa zone, Ethiopia. The study intended to assess crop productivity, technical efficiency and identify factors that determine poverty status of the farm households in the district based on cross sectional data. The study used partial factor productivity of crops specifically land productivity (output in kg per hectare) and income poverty of the households.

Since the concept of productivity in agriculture is wide and the concept of poverty is broad that the researcher does not cover in a short period of time and with limited budget, the study has certain limitations. The study focused on determinants of crop productivity and household poverty. Crop productivity in this study was partial factor productivity and did not use total factor productivity of crops. Poverty is multidimensional but this study focused only on income poverty. In addition to this, the study used cross sectional data which could not capture across time variability of productivity of crops and poverty status of the household. Despite these limitations, the study gives important light on the state of major crop productivity and situations of poverty of the households and the results and methods used may serve up as point of departure for further study that may address issues unseen in this study. Therefore, it is suggested that further study must be conducted on the dynamics of total factor productivity and multi-dimensional poverty status of the household in the area.

2. LITRATURE REVIEW

2.1. Basic Concepts for Productivity, Efficiency and Poverty

In microeconomic theory of production, the producer uses different inputs to produce outputs and in the process desires to maximize profit or revenues. Crop production is the process of producing crop output with the given level of input with the aim to maximize product. It is physical produce and can be reported in units of volume or weight. At basic level, productivty examines the relarionship between input and output in a given production process. Productivity is expressed in an output versus input formula for production activities. It does not merely define the volume of output, output obtained in relation to resources employed. In this context, productivity of a firm can be defined as the ratio of output to input Coelli *et al*. (1998). Particularly, crop productivity is defined as output per unit of input, where input can be land, labour and/or capital, and output is crop produced.

The concept of productivity is closely related with that of efficiency. Productivity and technical efficiency are the two interrelated terms but they are not precisely the same Coelli *et al*. (1998). In simple term, productivity is the quantity of a given output per unit of input. Technical efficiency (that part of efficiency which explains the physical performance of a firm) measures the relative ability of a farmer to get the maximum possible output at a given input or set of inputs. Technically efficient farmers are those farmers that are operating on the production frontier that represents the maximum output attainable from each input level. All feasible points below the frontier are technically inefficient points. Efficiency is also defined in terms of a comparison of two components (inputs and outputs), the highest productivity level from each input level is recognized as the efficient situation. Coelli and Battese (1998) further suggest that efficiency reflects the ability of a firm to obtain maximum output from a given set of inputs. If a firm is obtaining maximum output from a set of inputs, it is said to be an efficient firm.

Productivity of a firm can be improved either by producing output with fewer inputs, or producing more output for the same quantity of inputs. Thus, increasing productivity implies either more output is produced with the same amount of inputs or that fewer inputs are required to produce the same level of output Rogers (1998). The highest productivity (efficient point) is achieved when maximum output is obtained for a particular input level. Hence, productivity growth encompasses changes in efficiency, and increasing efficiency has been shown to raise productivity Rogers (1998).

Poverty is understood in many different ways. The state of 'poverty' encompasses notions of limitations to, and deprivation of, resources, often focused on lack of income or access to food, but also including other material, social and psychological deprivations that affect individual well-being is closely related to food insecurity and hunger UN (2011). Poverty is characterized by inadequacy or lack of productive means to fulfill basic needs such as food, water, shelter, education, health and nutrition. It is pronounced deprivation in well-being, and comprises many dimensions. It includes low incomes and the inability to acquire the basic goods and services necessary for survival with dignity. Poverty also encompasses low levels of health and education, poor access to clean water and sanitation, inadequate physical security, lack of voice, and insufficient capacity and opportunity to better one's life WB (2011). There is a strong interrelation between problems of poverty and low agricultural productivity Pender *et al*. (2001). The World Bank (Ravallion and Chen, 2008) states that a common method used to measure poverty is based on incomes or consumption levels. A person is considered poor if his or her consumption or income level falls below some minimum level necessary to meet basic needs. This minimum level is usually called the poverty line. When estimating poverty worldwide, the same benchmark poverty line has to be used, and expressed in a common unit across countries. Joseph (2013) defines poverty as the situation where a person's resources (mainly their material resources) are not sufficient to meet minimum needs.

2.1.1. Measurement of productivity and efficiency

Productivity can be measured on a partial factor or total factor basis (Coelli *et al*., 1998; Rogers, 1998). Partial factor productivity is measured as the ratio of output to a single input. The ratio of output to all inputs combined is the total factor productivity. Most productivity related studies in utilize partial factor productivity measures, specifically land productivity measured as yield per hectare (Collei and Battese, 1998; Amos *et al.*, 2004; Idiong *et al*., 2009).

The history of efficiency measurement in microeconomics goes back to Farrell (1957) who defined a simple measure of firm efficiency. In the approach, Farrell (1957) proposed that efficiency of any given firm is composed of technical and allocative efficiencies. According to Farrell (1957), technical efficiency (TE) is associated with the ability of a firm to produce on the isoquant frontier while allocative efficiency (AE) refers to the ability of a firm to produce at a given level of output using the cost-minimizing input ratios. On the other hand, technical efficiency and allocative efficiency are then combined to give economic efficiency, which is sometimes referred to as overall efficiency (Farell, 1957; Coelli *et al.*, 1998). Efficiency in production refers to scarce resources being used in an optimal fashion. 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).

There are two approaches in measuring efficiency: input oriented and output oriented. Input oriented measure of efficiency deals with by how much can input quantities be proportionally reduced without changing the output quantity produced. Alternatively, the output oriented measures of efficiency focus on the changes in output of a firm that may be achieved when using the same quantity of inputs. However, both measures will coincide when the technology exhibits constant returns to scale, but are likely to vary otherwise Coelli and Battese (2005).

2.1.2. The relationship between agricultural productivity and poverty

The poverty level of the rural household directly or indirectly depends on agricultural productivity and agricultural related practices. Historically, rates of poverty reduction have been very closely related to agricultural Performance, particularly, to the rate of growth of agricultural productivity. In simple terms, this indicates that the countries that have increased their agricultural productivity the most have also achieved the greatest reductions in poverty WB (2008). The role of agriculture in economic development has long been recognized. Agriculture has a multifunctional role to play in economies. Apart from providing food, agriculture is the main source of economic growth in Ethiopia and most of the sub-Saharan Africa countries (WB, 2011; Dethier and Effenberger, 2012).

Agriculture is very crucial sector that may reduce poverty in several ways like increase in crop productivity directly create more employment opportunities and improve the level of food security Goswami *et al.* (2010). Adverse implications for agricultural productivity may increase incidence of more poverty, which in turn is closely associated with hunger Ramasamy and Moorthy (2012). Thus agricultural productivity is an important part of food security which is an integral part of poverty eradication and hunger. Growth coming from agriculture is known to be twice as effective in reducing poverty as GDP growth originating from outside agriculture. Thus, even though high rates of economic growth may rapidly reduce the proportion of the population in absolute poverty but it is the direct and indirect effects of agricultural growth that accounts for virtually all the poverty decline. Therefore, farm productivity is a precondition for broad based economic development in most of the developing world WB (2008).

At the macro-economic level, growth in agriculture has been consistently shown to be more beneficial to the poor than growth in the other sectors. Furthermore, analysis reveals that increasing agricultural productivity has probably been the single most important factor in determining the speed and extent of poverty reduction. In terms of the role of agricultural productivity in reducing poverty, Thirtle *et al.*(2001) concluded from cross-country regression analysis that, on average, every 1% increase in labour productivity in agriculture reduced the number of people living on less than a dollar a day by between 0.6 and 1.2%. No other sector of the economy shows such a strong correlation between productivity gains and poverty reduction. Agricultural productivity growth, particularly cereal based intensification, offers the best potential for poverty reduction for large numbers of poor rural people in sub-Saharan Africa. There is a strong belief that agriculture will remain the driving force for rural transformation in Africa since no country is known to have managed to reduce poverty without commensurately improving agricultural productivity. Therefore, Production growth through the promotion of productivity is one of the main goals of countries Besharat *et al.*, (2011).

2.2. Analytical Framework for Productivity, Efficiency and Poverty

In this sub section production and production function, analysis of productivity and efficiency are reviewed.

2.2.1. Production Function

Production is the process of transforming factors of determinants of production into output. It is a process and as such it occurs through time and space. Production theory is the study of production or economic process of converting inputs into outputs. The cornerstone of the theory is the production function, which postulates a well-defined relationship between output and factor inputs. In explaining the relationship between output and input a production function model is necessary. A production function relates the physical output of a production process to physical inputs or factors of production.

2.2.2. Productivity and efficiency analysis

Productivity and efficiency analysis are based on the concept of the production function. The empirical estimation of production is a standard exercise in econometrics**.** The frontier production function or production frontier is an extension of the familiar regression model based on the theoretical premise that a production function represents an ideal maximum output attainable given a set of inputs. The estimation of frontier functions is the econometric exercise of making the empirical implementation consistent with the underlying theoretical proposition that no observed agent can exceed the ideal. In practice, the frontier function model is (essentially) a regression model that is fit with the recognition of the theoretical constraint that all observations lay within the theoretical extreme. Measurement of (in) efficiency is, then, the empirical estimation of the extent to which observed agents (fail to) achieve the theoretical ideal. The estimated model of production is the means to the objective of measuring inefficiency.

Starting from the first empirical application of Farrell (1957) several different approaches of frontier estimation and efficiency score calculation have been developed. The frontier methodologies have been widely used in applied production analysis. Technical efficiency measurements basically are carried out using frontier methodologies, which shift the average response functions to the maximum output or to the efficient firm. These frontier methodologies are broadly categorized under two frontier methodologies; parametric and non-parametric frontier models. The parametric frontier model may further be classified into deterministic and stochastic frontier models. The parametric models are basically estimated based on econometric methods and the non-parametric technical efficiency model, often referred to as data envelopment analysis (DEA), involves the use of linear programming method to construct a non-parametric frontier over the data (Coelli *et al*., 1998; Burhan *et al.*, 2009).

The selection of specific frontier model depends upon many considerations such as the type of data, cross-sectional or panel data, the underlying behavioral assumptions of firms, the relevance to consider and extent of noise in the data and the objective of the study. Coelli *et al*. (1998) agreed that stochastic frontiers are likely to be more appropriate than non-parametric in agricultural applications of efficiency analysis.

Parametric frontier model can further be classified into deterministic and stochastic frontier methods. The deterministic model assumes that any deviation from the frontier is due to inefficiency, while the stochastic approach allows for statistical noise. The primary criticism of the deterministic frontier model is that no account is taken of the possible influence of measurement errors and other noise upon the frontier Coelli *et al*. (1998). This study used stochastic frontier model for the analysis. Therefore, more of the review below mainly focuses on stochastic frontier model in efficiency and productivity analysis.

2.2.2.1. Deterministic frontier model

According to Coelli (1995), this model doesn`t take account the possible influences of measurement errors and other noises up on the shape and positioning of the estimated frontier.

The deterministic model assumes that any deviation from the frontier is due to inefficiency. But in most cases, there exists random error or noise especially in agriculture. The primary criticism of the deterministic frontier model is that no account is taken of the possible influence of measurement errors and other noise upon the frontier Coelli *et al*. (1998).

Most empirical studies on technical efficiency analysis in agriculture used stochastic frontier model due to the very nature of agricultural output, which is affected by natural hazard, climatic condition and measurement errors that could attribute to the presence of noise in the data. Hence, most studies on technical efficiencies in agriculture have used stochastic frontier model to account for random noise (Battes *et al*., 1995; Coelli *et al*., 1995; Ayalneh, 2011; Endrias *et al.*, 2013; Wassie, 2014).

2.2.2.2. Stochastic frontier model

Most empirical studies on technical efficiency analysis in agriculture used stochastic frontier model due to the very nature of agricultural output, which is affected by natural hazard, climatic condition and measurement errors that could attribute to the presence of noise in the data. Hence most studies on technical efficiencies in agriculture have used stochastic frontier model to account for random noise. The modeling, estimation and application of stochastic frontier (SF) production functions to economic analysis has assumed prominence in econometrics and applied economic analysis. Early application of SF to economic analysis include the pioneer seminal work of Farrell (1957), Battese and Coelli (1995), Battese *et al.* (1996), Aigner *et al* (1977), Battese and Corra (1977) and Meeusen and Broeck (1977) among others.

The SFM is recommended when analyzing farm level data where measurement error, some missing information and presence of risks factors are likely to have a significant impact Coelli (1996). The main advantage of this model is the ability of the model to separate the random error or noise, such as weather that are stochastic and not due to operator inefficiency, from deviations arising from technical inefficiency. Due to this, most empirical studies especially in agriculture where random errors due to random shock and measurement error are high focus on stochastic frontier model. Coelli *et al*. (1998) recommended that SPF is more appropriate than DEA and deterministic models in agricultural applications, especially in developing countries, where the data are heavily influenced by measurement errors, and the effect of weather, disease, etc plays a significant role. The other attractive feature of stochastic frontier model is that it permits the estimation of standard errors and test of hypothesis using traditional maximum likelihood methods which were not possible with the deterministic model Coelli *et al*. (1998).

With regard to functional forms, Coelli *et al*. (1998) discussed three common functional forms for SPF namely Cobb-Douglas, Translog and Zellner-Revankar generalized production functions. Each functional form has its own strength and shortcomings. The Cobb-Douglas functional form has been commonly used in the empirical estimation of frontier models. Its simplicity is a very attractive feature. Cobb-Douglas production model was used by Gupta *et al*. (2012) to investigate the factors impact on agricultural productivity. Battese and Broca (1996) pointed out that Cobb-Douglas and Translog are the two most common functional forms that have been used in empirical studies on production, including frontier analysis. The other characteristic of stochastic frontier model associated with inefficiency effects is the type of distributional form for the u_i's. This characteristic, specification of appropriate distributional form, is the main criticism of the stochastic frontier model for it has generally no priori justification for its selection. Half-normal distributional form is the most common and almost universally assumed in empirical studies of technical efficiency. There are of course other general distributional forms such as truncated-normal, exponential and the two-parameter gamma distribution. In addition to the selection of appropriate functional form, the other main issue in efficiency analysis is prediction of firm level efficiencies that is related to u_i's. The absence or the presence of technical inefficiency in a given data can easily be tested using the generalized ratio test Coelli (1995).

Once the functional form for SPF is selected, distributional form for inefficiency component is assumed and the presence of inefficiency is tested the next issue in SPF analysis is decide the estimation procedure to analyze the inefficiency effects model. In identifying determinants of efficiency researchers mostly use two types of modeling. One way of modeling determinants of efficiency is linear regression method in a second stage analysis after efficiency estimates are obtained for each decision-making in the first stage estimation. The other way of modeling determinants of inefficiency is estimating these variables using a one-stage analysis with the production frontier. Regarding these two methodologies, there are debates whether the two-stage estimation procedures produce better estimates of efficiency as well as locate appropriate variable that determines the inefficiency level or not. But Battese and Coelli (1995), Coelli *et al*. (1998), and many others favored one stage estimation procedure from two angles. From theoretical point of view, they argue that determinants of efficiency can have direct impact on efficiency. Thus, incorporating these factors in the model would make the estimation procedure more appropriate. The other side of their argument lies on the consistency of the assumptions involved. They argue that, in the first stage estimation, the inefficiency effects are assumed to be independently and identically distributed in order to predict the value of technical inefficiency. However, in the second stage the predicted inefficiency effects are assumed to be a function of a number of firm specific factors, which implies that they are not identically distributed, unless all the coefficients of all the factors are simultaneously equal to zero.

Maximum likelihood estimation method is used for stochastic frontier model assuming inefficiency exists. In other cases, the average response function is estimated using OLS estimator assuming that all firms are efficient. Based on different literatures, this study used Cobb-Douglas specification of stochastic frontier model and half normal distributional assumptions of the inefficiency component. The estimation method used was one stage maximum likelihood estimation method that used to estimate simultaneously the Cobb-Douglas stochastic frontier model and determinants of inefficiency. Generally for SFM, there are theoretical agreements among researchers that the arbitrary nature of distributional assumption and the restrictive nature of specifying a given functional form as disadvantages, its consideration of noise on the data and the possibility of testing hypothesis are the most appealing characteristics of stochastic frontier model Coelli *et al*. (1998).

The art of modeling poverty seem to be preoccupied in getting the best criteria for the judgment of the poverty status of individuals or households. The practice of discrete choice models in the analysis of determinants of poverty has been popular approach Amuedo and Dorantes (2004). Among this, many literature shows that binary logit model is used to estimate the probability of a household being poor conditional up on some characteristics. The literature shows that regardless of the definition of poverty line, the most commonly used dependent variables in poverty functions are binary indicators logit regressions of poverty status (poor or non-poor) used as a tool of analysis in this kind of study (Mok *et al.*, 2007; Amjad and Mqbool, 2008).

2.3. Empirical Literature on Productivity, Efficiency and Poverty

In this sub section empirical literature consists of studies made earlier which are related to determinants of crop productivity, efficiency and poverty were reviewed.

Efficiency estimation without clearly identifying important socio economic and demographic, institutional and policy variables, has limited importance for policy and management purposes. Therefore, identification of its determinant and analysis of the underlying factors of inefficiency are given priority for efficiency analysis.

The determinants of efficiency can be identified as policy and institutional factors (credit access, extension, input access, market infrastructure etc), environmental factor (pest, disease, resource depletion, population pressure etc), farm characteristics (farm location and distance, soil fertility, availability of water), farmer characteristics (level of education, sex and age of household head, family size etc) based on many researchers' study result (Chirwa, 2007; Javed, 2009; Larry *et al*., 2011; Abba, 2012; Endrias *et al*., 2013; Wassie, 2014). The literatures were reviewed for better information regarding the selection of determinants of efficiency. The empirical literature of productivity, efficiency and poverty analysis are given below.

There is a very strong emphasis in the literature on the quantity and quality of inputs for crop productivity. The size of land available (Abubakar, 2006), planting materials, particularly high quality seeds (Shehu *et al*., 2010; Akintayo, 2011), and labor (both family and hired) (Otitoju and Arene, 2010; Shehu *et al*., 2010; Akintayo, 2011), the quantity of fertilizer (Akintayo, 2011), the amount spent on agrochemicals like pesticides and herbicides (David *et al*., 2009; Abubakar, 2006), and mechanization (the use of a tractor) (Adesoji, 2008), are all important predictors of productivity. However, suboptimal utilization of any of these inputs has a negative effect on productivity (Peke, 2008; Otitoju and Arene, 2010). Availability of good quality affordable inputs is clearly a major constraint for smallholder farmers David *et al*. (2009).

Ukoha *et al*. (2010) used a multiple linear regression model used to analyze factors that affect agricultural productivity in Nigeria. Based on this literature, linear production function and other transformed form of the production function used like as multiple linear regression and select the appropriate one after fitting and using some measures of goodness of fit.

Nyagaka *et al.* (2010) assessed the technical efficiency in resource use and identified the underlying determinants of variations in production efficiency for smallholder potato producers from Nyandarua North District, Kenya. They used a dual stochastic parametric decomposition technique to derive technical efficiency indices while a two-limit Tobit model was used to examine the effects of socio-economic characteristics and institutional factors on the derived technical efficiency scores. The study results showed that education, access to extension, access to credit and membership in farmers’ association have positive and significant effect on technical efficiency of smallholder potato producers in the district.

Javed (2009) determined efficiency of cotton-wheat and rice-wheat systems in Punjab, Pakistan, considering socioeconomic and farm specific factors which were as likely to affect the level of technical, allocative and economic inefficiency. Accordingly, in order to identify sources of technical, allocative and economic inefficiency, inefficiency scores were regressed on socio-economic and farm specific variables, using Tobit regression model. The result indicated that years of schooling, contact with extension agents and access to credit variables were negatively related to inefficiency. On the other hand, age of farm’s operator and farm to market distance variables are positively related with the technical inefficiency.

Olowa (2010) estimated sources of technical efficiency among smallholder maize farmers in Osun State of Nigeria using a Cobb-Douglas stochastic production frontier model. The study result showed that using hybrid seed and households membership in farmers association affects technical efficiency positively and significantly for smallholder maize farmers.

Larry *et al.* (2011) conducted a study on estimation of farm level technical efficiency in small scale maize production in the Mfantseman Municipality in the Central Region of Ghana by using stochastic frontier approach. The frontier analysis result shows that the inputs seed, fertilizer and labor force had positive effect on maize yield. Seed and labor are significant but fertilizer not. Results also indicated that the mean technical efficiency of small scale maize production in the study area is 58%; the number of years of school the farmer has had in formal education, age of the farmer, household size, and off - farm income activities of the farmer affect technical efficiency of maize producers.

Chirwa (2007) estimated technical efficiency among smallholder maize farmers in Malawi and identified sources of inefficiency using plot-level data. The researcher found that smallholder farmers in Malawi are inefficient. The result revealed that inefficiency declines on plots planted with hybrid seeds and for those controlled by farmers who belong to households with membership in a farmers association.

Chimai (2009) conducted a study on technical efficiency and its determinants in sorghum yield in Zambia. The study used Data Envelopment Analysis (DEA) followed by an Ordinary Least Squares (OLS) regression of the DEA scores on the household and farm characteristics. The study result shows that technical efficiency in sorghum production was affected by household size, number of dependents, gross value of field crop production, value of assets, income from livestock activities, access to credit, extension frequency, seed rate and whether a household is located in a low rainfall area or not. Average technical efficiency in sorghum production among the smallholder farmers was 34 percent.

A study done by Abba (2012) on the technical efficiency of sorghum production and its determinants used stochastic frontier production function which incorporates a model of inefficiency effects by using farm level data collected from a sample of 100 sorghum farmers in Hong local government area of Adamawa state. The study result shows that land, seed, and fertilizer were the major factors that determine sorghum yield. Education, extension contact and household size were major explanatory variables that had significant effects on the technical inefficiency among the sorghum producers.

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

Wassie (2012) used Cobb Douglas production function, to determine elasticity of inputs and the level of efficiency of each producer by applying two-stage estimation method for small scale wheat producer farmers in Ethiopia. The researcher also used the estimated level of efficiency as dependent variable in the Tobit model which was used to determine factors that affect efficiency. The study result showed that, on average, the total wheat seed production can be enhanced by nearly 20 percent, keeping inputs and current production technology constant (the mean TE was 79.9).

Wassie (2014) conducted a study on technical efficiency of major crops in Ethiopia. The researcher used average and stochastic frontier analysis. The results of both depicted that all the inputs (land, urea, DAP, seed and labor) had positive and significant effect on yield of crops. The mean technical efficiency for major crops was 63.56%. The inefficiency effect analysis shows that education, participation in soil and water conservation, livestock ownership and adopting of improved seed have negative and significant effect on technical inefficiency.

Alemu *et al.* (2009) investigated efficiency variations and factors causing (in)-efficiency across agro-ecological zones in East Gojjam, Ethiopia. Stochastic frontier analysis was employed and the result showed that, smallholder farmers in the study areas had a mean technical efficiency of 75.68 percent. The results also revealed there is a significant difference in technical efficiency among agro-ecological zones. Besides, education, proximity to markets, and access to credit were found to reduce inefficiency levels significantly.

Essa *et al*. (2012) investigated a study on analysis of resource use efficiency in small mixed crop-livestock agricultural system based on the data from rural households in central high lands of Ethiopia. The data envelopment analysis (DEA) result shows smallholder that small holder farmers are resource use inefficient in the production of major crops with mean technical, allocative and economic efficiency levels of 0.74, 0.68 and 0.50, respectively. A Tobit model regression results on the determinants of inefficiency reveal that livestock ownership and participation in off-farm activities have negative effect on inefficiency whereas, large family size and membership to associations affects positively the inefficiency.

According to the study by Amjad and Maqbool (2008) conducted a study on determinants of rural poverty in selected districts of Punjab. The researcher used binary logistic regression model for data analysis. The study result showed that the chance of a household being poor increased due to increase in household size, dependency ratio while, education, value of livestock, remittances and farming productivity decreased the likelihood of being poor. Moreover, the socio-economic opportunities as represented by the availability of infrastructure in the residential region also play a significant role in the level of poverty faced by a household. Education of the household head, area of cultivated land, changes in household size, value of livestock owned and mean time to services and residential place were significantly related to the probability of being poor.

Germano *et al*. (2005) analyzed household level data to examine the determinants of poverty status in Kenya. The data was analyzed by using probit model. The study result shows that poverty status is strongly associated with the level of education, household size and engagement in agricultural activity, both in rural and urban areas. According the study carried out by Apata *et al*. (2010) on chronic poverty in rural Nigeria using the probit model shown that access to micro-credit, education, participation in agricultural workshops/seminars, livestock asset, and access to extension services significantly influence the probability of households' exiting chronic poverty. The researcher also found that female headed household' and distance to the market increases the probability of persistence in chronic poverty.

Alem (2007) used the logistic regression model for the analysis of determinants of food insecurity in rural households in Tehuludere Woreda, South Wollo Zone of the Amhara region. The researcher found that participation on on-farm activities, family size, annual production, farm size, dependency on food aid, wealth status and perception about land tenure security are the most important determinants of food insecurity.

The study conducted by Ayalneh *et al.* (2005) on rural poverty by using logistic regression model indicated that age of household head, sex of household, number of oxen owned, land holding per adult equivalent, percapita income, education of household head, are significant in determining household poverty in rural Ethiopia. Based on the results of the logistic regression model the probability of a household being poor tends to diminish as age of the household head increases; and the probability of being poor is higher for male headed households than female headed households when per capita food energy consumption is considered.

Ayalneh (2011) conducted a study on analysis of poverty and its covariates among smallholder farmers in the Eastern Hararghe highlands of Ethiopia by using the ordered probit model. The researcher suggested that the probability of being poor depends on access to non-farm income, household size (affects the household well being negatively), involvement in governance, social and production related networks found to be strongly associated with the probability of a household being poor. Household size and age of the household were also found to affect the household's wellbeing negatively, according to the study results.

A study conducted by Adem (2013) by using multiple linear regression with the OLS method of estimation was used to identify the determinants of household's annual income per adult equivalent. The result showed that age of the household head, mean years of education of the school age family members, livestock size, farm size, religion, property ownership at early childhood and parent's economic status are the most significant determinants of current household annual per adult equivalent income. Income poverty was affected negatively by mean years of education of the households, property ownership at early childhood, total farm land size, and livestock size. Additionally, income poverty was higher among the old age; those participated in Kebele administration and those with non-poor parental economic background. The study also analyzed food poverty by using logistic regression model and the result depicted that livestock size, property ownership at early childhood, and irrigation use reduce the household's probability of being food poor, whereas the odds for being poor increases for the Muslim as compared to the Christian.

A lot have been done on the technical efficiency of crop productivity at a national, regional as well as district level in Ethiopia till now. In general, technical efficiency of smallholder farmers has been studied in Ethiopia regardless of area of study and its crop specificity; it is still an important area of policy concern. This is because smallholder farmers are major constituent of agricultural producers in developing economies. Therefore, estimation of technical efficiency and identification of its determinants for smallholder farmers has a paramount importance for appropriate policy formulation and improving crop productivity. This kind of study is also highly relevant to Ethiopia where resources are meager, opportunities for developing and adopting better technologies are scarce and moreover, most grain crops are produced by smallholder farmers. The preceding discussion shows that most of the empirical works have focused on a particular agro-ecology, or concentrated on technical efficiency otherwise they analyzed specific crop production efficiency. In most literature Stochastic Frontier analysis is frequently used for productivity and efficiency analysis.

As most literature shows that stochastic frontier with Cobb-Douglas functional specification has a wider application in efficiency analysis. Most of those studies conducted earlier in Ethiopia, have focused on the technical efficiency, and not so much on factor productivity. Therefore, this study was aimed at estimating elasticity of crop productivity with respect to factor inputs, evaluating the return to scale, determining technical efficiency of smallholder crop producers and determining the underlying factors affecting the existing inefficiencies.

The study used data from *teff*, wheat bean, barley and sorgum producers in Menz Keya Gebriel district. As most literature also shows productivity and efficiency analysis done for a single crop or major crops by aggregation. But this study considers the analysis of productivity of each crop type and determinants of inefficiency simultaneously using one stage estimation method for each crop separately. Additionally, this study tried to see the determinants of household poverty and the effect of aggregate crop productivity on poverty status of the household by using logistic regression model. In doing so, the study attempted to fill the knowledge gap on the current level of efficiency, elasticity of crop productivity with respect to factor inputs, further productivity capacity of crops and the underlying factors causing inefficiency particularly in the study areas and determinants of household poverty. The analysis of determinants of crop productivity, TE and household poverty in this study vary from other studies were considering many crops the household cultivated in the analysis separately (Independently, the model was fitted for each crop type), functional form specification of production function, estimation method of the stochastic frontier and inefficiency effect, the hypothesis tested and identifying of determinants of household poverty at the same time. Therefore, with this unification the study will contributed additional literature.

3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

3.1.1. Location of the study area

Menz Keya Gebriel is one of the woredas in the Amhara region of Ethiopia. It is located 327 km northwest of Addis Ababa and about 197 km northwest of Debrebirhan town in the North Shewa zone. Menz Keya Gebriel is bordered on the southeast by Menz Lalo Midir, on the southwest by the Jamma River which separated it from Moretna Jiru, on the west by Merabete, on the northwest by the Qechene River which separates it from the Debub Wollo Zone, and on the northeast by Menz Gera Midir. The administrative center of this woreda is Zemero. Menz Keya Gebriel was part of the former Gera Midirna Keya Gebriel woreda.

3.1.2. Demographic characteristics of the study area

Based on the information obtained from the woreda's Finance and Rural Development Office (2015), the woreda has a total population of 58,449, of whom 54,449 (27,261male and 27,517 female) are rural and 3,671 urban inhabitants. In the woreda, there are a total of 8,452 households of whom 7,824 are rural inhabitant and the rest 628 are urban inhabitant households.

3.1.3. Economic activities in the study area

The study area's farming system is a mixed farming system mainly based on crop production activities and livestock production. Agriculture is dependent on the meher season largely dependent on rainfed and with minimum or less irrigation practices. In the study area, cereals, pulses, oilseeds, fruits and vegetables are produced by farmers. Crop production in the region as well as in the study area is cereal dominated. The main crops grown in the woreda include *teff*, wheat, barley, sorghum, chick peas and beans. Wheat, *teff*, sorghum and bean are the most important crops, serving as both the main food and cash crops. Cattle, sheep, goats, donkeys, horses, and chickens are the most common livestock types reared by households. Livestock are kept partly as capital, which can be turned into cash when required. Crop sales make the largest contribution to household income together with sheep and goat and other livestock for their cash earnings (the information obtained from the woreda's agricultural office in July, 2015).

3.2. Sample Size Determination and Sampling Techniques

The ultimate objective of sampling is to select a set of representative elements from a population. Random sampling enhances the likelihood of accomplishing this objective and allows for the objective assessment of reliability of the sample.

North Shewa comprises of twenty seven woredas. Menz Keya Gebriel woreda is one of the woreda in the zone. It is selected purposively among the woredas in the zone. The woreda is the newly formed woreda separated from Gera Midirna Keya Gebriel woreda. The woreda is far from the zone town Debrebirhan. The researcher selected the woreda purposively to study crop productivity and its impact on household poverty. In the study area, there are 7,824 rural households and these are considered as the population of the study. From those households, representative sample households were selected and the appropriate sample size was determined by appropriate techniques.

To get the representative sample households from the study district, the researcher employed stratified random sampling based on agro ecological zones. The woreda is classified into two agro climatic zones, midland and lowland based on the information obtained from the district's agricultural office. The midland and low land are considered as a stratum. After determining the sample size, the total sample was allocated to each stratum by sample allocation proportional to size procedure. Then, the required sample was selected by systematic random sampling technique from each climatic zone (strata). The sample size determination depends on the poverty status of the household because of the availability of information. Depending on the information obtained from the district's agricultural office, there are 7,824 rural households who practiced agricultural activities, of whom 1,254 are poor.

Those 1,254 poor households are engaged in safety-net program according to the information obtained from the office. Sample size determination has its own scientific formula for sample size in sampling for proportions. The categories for proportion are poor and non-poor households. (All the above numbers are 2015 data taken from the woreda's different office by the researcher). The sample size is calculated as follows:

$$n = \frac{\frac{Z^2{}_{\alpha/2} PQ}{d^2}}{1+\frac{1}{N}\left(\frac{Z^2{}_{\alpha/2} PQ}{d^2}-1\right)} = \frac{n_0}{1+\frac{1}{N}(n_0-1)} \qquad (3.1)$$

Where, $n_0 = \frac{Z^2{}_{\alpha/2} PQ}{d^2}$

P is proportion of poor households,

Q is proportion of non-poor housholds,

Z is the critical value,

d is the marigin of error(maximum tolerable error),

N is the population size (total number of rural households in the district)

n is sample households(sample size)

P=(number of poor households)/(total number of households)= $\frac{1,254}{7,824} = 0.160276 \approx 0.16$

Q=(number of non-poor households)/(total number of households)= $\frac{6570}{7,824} = 0.8397 \approx 0.84$

$Z_{\alpha/2}$=1.96 with α =0.05 is the critical value for a 95 % confidence level, and d is the marginal (absolute) of error. The larger the sample the more precise estimates. But cost, time and operational constraints limit to do so. Thus, considering these constraints and the desired levels of precision, relative error was decided to be 0.05.

Then n_0 can be calculated as follows

$$n_0 = \frac{Z^2{}_{\alpha/2} PQ}{d^2} = \frac{(1.96)^2\,(0.16)(0.84)}{(0.05)^2} = \frac{0.5163}{0.0025} = 206.5 \approx 207$$

If $\frac{n_0}{N} < 5\%$ take n_0 as the sample size; if not, use the formula $n = \frac{n_0}{1+\frac{1}{N}(n_0-1)}$ to fix the sample size. $\frac{n_0}{N} = \frac{207}{7824} = 0.0265 < 5\%$ then according to Cochran (1977). Take $n_0 = n$ as the sample size. So the sample size is n= 207. In this study 207 rural households were used to collect data.

From a total of 7,824 rural households, those who live in midland are 4,896 and the remaining 2,928 live in the low land based on the information obtained from the woreda's agricultural office and kebeles in 2015. To determine how much sample size was taken from each agro ecological zone (stratum) the researcher employed proportional allocation. To allocate the samples for each stratum the following formula is used.

$n_h = n\frac{N_h}{N}$ Where, h =1, 2 number of strata

N is the total number of households

n total sample size

n_h Sample size in the h^{th} stratum

N_h Population size in the h^{th} stratum

This stratification is described as stratification with proportional allocation of n_h. It gives a self-weighting sample. Then after having the population size for each stratum, allocate the total sample to each stratum by using the above formula. Midland is considered as 1^{st} stratum and lowland as the 2^{nd} stratum.

$$n_1 = n\left(\frac{N_1}{N}\right) = 207\left(\frac{4896}{7824}\right) = 129.5 \approx 130 \text{ and}$$

$$n_2 = n\left(\frac{N_2}{N}\right) = 207\left(\frac{2928}{7824}\right) = 77.4 \approx 77$$

$n_1 + n_2 = n$ The sum of the sample size from each stratum gives the total sample size and

$N_1 + N_2 = N$ The sum of the population size from each stratum gives the total population.

In this study $n_1 = 130$ from midland (stratum 1) and $n_2 = 77$ from lowland (stratum 2) and a total sample of size 207 rural households were selected for collecting data. Finally, systematic sampling technique was employed in each stratum to get the unbiased representative sample units from each stratum. In systematic sampling technique the interval for sample selection is k=N/n= 7824/207=37.79≈38 for each stratum. Then select the sample household by using the interval until the required sample was reached in the two strata accordingly.

3.3. Data Types and Methods of Data Collection

The study used primary data collected from sample households so as to meet the objectives of the study. The Primary data were collected from sample households through interview schedule administered by trained enumerators. Enumerators, who are familiar with the study area, who can understand local language and who have prior experience were recruited. Then, in order to facilitate data collection, the enumerators were trained regarding the objectives of the study, content of the questionnaire, and data collection procedure. Sample household interview employed to obtain household level data on crop production, source of income, socio economic characteristics of sample households. The primary data included detail information of household level data on household characteristics, farming activities, crop production and productivity, institutional services for farming, non-farm activities, income, and other data related to various sources of income of the households. The survey was conducted in July and August, 2015 using the questionnaire given in Appendix 3.

3.4. Methods of Data Analysis

The basic aim of modeling is to derive a mathematical representation of the relationship between an observed response variable and a number of explanatory variables, together with a measure of the inherent uncertainty of any such relationship. Statistical models constructed for response variables are at best an approximation to the manner in which an observable variable depends on other variables Gujarati (1995).

Some models are more appropriate than others, but typically, for any set of data, there are a number of models, which are equally well suited to the purpose in hand, and the basis for choosing a single model from amongst them were based on statistical grounds. Descriptive statistics (mean, percentage, range, variance and standard deviation) was used to summarize the variables used in the study. Among Econometrics models, Cobb-Douglas stochastic frontier model and logistic regression model were used to analyze the data.

3.4.1. Stochastic frontier model (SFM)

The general stochastic frontier model developed independently by Aigner *et al*. (1977) and Meeusen, and ven den Broeck (1977). Stochastic frontier production models use a composed error structure with a one sided component and a two sided symmetric term. One-sided component indicates technical inefficiency effects associated with technical inefficiency of a producer while two-sided component accounts for measurement errors in production and other random effects which are not under management control. Many studies used the stochastic production function approach to determine the level of output elasticities and technical efficiency by fitting stochastic frontier model (Arega *et al*., 2005; Endris, 2010; Essa *et al*., 2012; Susan *et al*., 2014 and Wassie, 2014).

In this study, Cobb-Douglas stochastic frontier model used for the analysis of productivity and efficiency of five crops (*teff*, wheat, barley, bean and sorgum) separately by assuming crop productivity (Y) as a function of explanatory variables or inputs of production (seed, fertilizer, oxen pair day and labor force) for stochastic frontier and variables that affect inefficiency for the production of these crops. The model specified as follows:

Y_i = f (X_i, β) exp(ε_i) i=1, 2, . . ., n

$$Y = e^{\beta_0} X_1^{\beta_1} X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} \exp(\varepsilon) \qquad (3.2)$$

Composite error term $= \varepsilon_i = v_i - u_i$

Yield (Y): yield, which is the dependent variable in the estimation of production functions, is measured in kilogram per hectare for the specified crops.

Explanatory variables (X): the variables used in the production process and that determine productivity. These include seed, fertilizer, oxen pair day and labor considered as inputs for crop production.

All inputs and outputs were transformed to log values in estimating the Cobb-Douglas stochastic frontier production function. Then logarithmic transformation of the model in equation (3.2) becomes:

$\ln(Y_i) = ln(X_i)\beta + \varepsilon_i$, $\varepsilon_i = v_i - u_i$ i = 1, 2, . . . n

$$\ln(Y_i) = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \varepsilon_i \qquad (3.3)$$

Where:

Y=Output in kg/hectare;

X_1= Seed rate in kg/hectare;

X_2= Fertilizer in kg/hectare;

X_3= Oxen in oxen-pair days/hectare;

X_4 = labor force in labor-days/hectare;

β_0= Intercept term or scale parameter;

β_j= Output elasticity of j^{th} input (j= 1, 2,…,5);

ε_i= The error term that is composed of two elements. $\varepsilon_i = v_i - u_i$

v_i - is the disturbance error term, independently and identically distributed as N (0, ${\sigma_v}^2$) intended to capture events beyond the control of farmers including measurement error; and

u_i - is a non-negative random variable that is independent of $\boldsymbol{v_i}$ and is half normally distributed as N^+ (0, ${\sigma_u}^2$) intended to capture technical inefficiency effects in the productivity of a specified crop measured as the ratio of observed output to maximum feasible output of the crop. It allows actual production to fall below the frontier but without attributing all short fall in output from the frontier as inefficiency.

The ratio of the observed yield for the i^{th} producer relative to the potential yield (defined by the frontier production function), given the level of input vector x_i, gives the technical efficiency of the i^{th} producer.

$$TE_i = \frac{\text{f}(X_i,\beta)\exp(v_i)\exp(-u_i)}{\text{f}(X_i,\beta)\exp(v_i)} = \exp(-u_i) \qquad (3.4)$$

The stochastic production frontier at a technically efficient household would represent the maximum attainable yield Y_i^* as:

$$Y_i^* = \text{f}(X_i,\beta)\exp(v_i) \quad \text{i=1, 2, . . ., n} \qquad (3.5)$$

The farm-specific technical efficiency is defined in terms of observed yield (Y_i) to the corresponding frontier yield (Y_i^*) using the available technology as:

$$T\hat{E}_i = \frac{Y_i}{Y_i^*} = \frac{E[Y_i/u_i, \ X_i]}{E[Y_i/u_i=0, \ X_i]} = \text{E [exp } (-u_i)/\varepsilon_i] \quad (3.6)$$

Technical inefficiency $= 1 - T\hat{E}_i$

Technical efficiency takes values in the interval [0, 1] where 1 indicates a fully efficient farm household.

In this study, a total of five production functions were fitted, individually. The variable definitions are the same for all functions. Specific to major crops production function, it refers to all observations of plots producing *teff*, wheat, barley, bean and sorgum. The logarithmic transformed Cobb-Douglas type stochastic frontier model for the five crops productivity (*teff*, wheat, barley, Bean, and Sorgum) individually were specified as follows:

$$\ln(Y_{Ti}) = ln\beta_{T0} + \beta_{T1}lnX_{T1} + \beta_{T2}lnX_{T2} + \beta_{T3}lnX_{T3} + \beta_{T4}lnX_{T4} + \varepsilon_{Ti}$$
$$\ln(Y_{Wi}) = ln\beta_{W0} + \beta_{W1}lnX_{W1} + \beta_{W2}lnX_{W2} + \beta_{W3}lnX_{W3} + \beta_{W4}lnX_{W4} + \varepsilon_{Ti}$$
$$\ln(Y_{Bri}) = ln\beta_{Br0} + \beta_{B1}lnX_{Br1} + \beta_{Br2}lnX_{Br2} + \beta_{Br3}lnX_{Br3} + \beta_{Br4}lnX_{Br4} + \varepsilon_{Bri} \quad (3.7)$$
$$\ln(Y_{Bi}) = ln\beta_{B0} + \beta_{B1}lnX_{B1} + \beta_{B2}lnX_{B2} + \beta_{B3}lnX_{B3} + \varepsilon_{Bi}$$
$$\ln(Y_{Si}) = ln\beta_{S0} + \beta_{S1}lnX_{S1} + \beta_{S2}lnX_{S2} + \beta_{S3}lnX_{S3} + \varepsilon_{Si}$$

Where:

$\beta_{T0}, \beta_{W0}, \beta_{Br0}, \beta_{B0,} \ and \ \beta_{S0}$ are intercept terms or scale parameters for *teff*, wheat, barley, bean and sorgum production functions, respectively;

β_j*'s* (j= 1, 2, 3, 4) are output elasticities of j^{th} input under different functions;

The subscripts T, W, Br, B and S stands for production functions of *teff*, wheat, barley, bean and sorgum, respectively;

i= number of observations (samples) for each crop production (i= 1, 2, 3, . . . , 204 for Teff; i= 1, 2, 3, . . . , 187 for Wheat; i= 1, 2, 3, . . . , 115 for Barley; i= 1, 2, 3, . . . ,172 for Bean and i= 1, 2, 3, . . . , 80 for Sorgum).

For each of the above five production function, there was a composite error term (ε_i) which consists of the random disturbance component (v_i) and the inefficiency component (u_i) as defined above. For the above five Cobb-Douglas stochastic frontier model, there are also respective inefficiency effects due to the existence of the inefficiency component u_i.

All inputs and outputs were transformed to their corresponding log values in estimating the Cobb-Douglas stochastic frontier production function. As the log value of zero is undefined, for the variables out of which production is possible (fertilizer) zero values in the data set were changed to nearly zero (0.0001) value before transforming the data to log form (Wassie, 2014).

The coefficients of the Cobb-Douglas stochastic frontier production function of basic inputs are called the elasticities for the respective input in the function. In other words, the MLE values of the coefficients can be interpreted as elasticity of production. The elasticity of output with respect to the i^{th} input measures the responsiveness of output to a 1% change in the i^{th} input. The sums of the coefficients represent return to scale in the production function. The measure of returns to scale, representing the percentage change in output due to a proportional change in use of all inputs, is estimated as the sum of output elasticities for all inputs used in the production. If the value is greater than, equal to, or less than one, we have increasing, constant, or decreasing returns to scale, respectively.

Determinants of inefficiency: A number of determinants of inefficiency in production have been identified from previous studies. The socioeconomic and biological variables, chosen in reference to former studies and logical reasoning are used in identifying the determinants of inefficiency. Most literature used to analyze determinants of efficiency rather than inefficiency. However, the only difference between them is only on the interpretation. This is due to the existence of the inefficiency component in the composite error.

As explained above in this paper, u_i is assumed to follow half-normal distribution, such that

$$u_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \dots + \delta_k Z_{ki}$$

$$u_i = \delta_0 + \sum_{j=1}^{k} \delta_j Z_{ij} \qquad (3.8)$$

Where: i=1,2,…,n and j=1,2, . . ., k ; number of explanatory variables in the inefficiency effect

δ_0: The constant term for the inefficiency effect

δ_j: The parameter (coefficients) for the j^th^ independent inefficiency variable in the inefficiency effect

Z_{ij} –are different variables that affecting inefficiency identified in the literature.

3.4.1.1. Estimation method of the model parameters for SFM

The one stage estimation procedure of the inefficiency effects together with the production frontier function is implemented in the study. The maximum likelihood estimates (MLE) of the parameters of stochastic frontier production function and inefficiency effect were simultaneously obtained using Cobb-Douglas stochastic frontier model in STATA.

For the stochastic frontier model specified above as $ln(y_i)= \ln(f(x_i;\beta))+v_i-u_i$; estimating the model parameters requires; specification of a functional form for the deterministic component, an assumption about the distribution of the random variable v_i, and an assumption about the distribution of the random variable u_i. Given a particular specification for the random variables u_i and v_i, the Maximum Likelihood (ML) technique is used to estimate the unknown parameters. The component v_i is assumed to be normal distribution and the component u_i can assume half normal, exponential or truncated normal distribution. The component u_i is assumed to be positive representing production inefficiency. Most often u_i is assumed to be half-sided normal. The maximum likelihood estimation for normal v and half-normal u (normal-half normal) assuming independence of v and u the joint density function results as the product of individual density functions derived as follows.

$u_i \sim N^+(0, \sigma_u^2)$ and the noise is normal $v_i \sim (0, \sigma_v^2)$

The density of u_i is given as

$$f(u_i) = \frac{2}{\sigma_u\sqrt{2\pi}} \exp\left(\frac{-u_i^2}{2\sigma_u^2}\right) \qquad (3.9)$$

With moments E (u) $=\frac{\sqrt{2}}{\sqrt{2\pi}}\sigma_u$ and $V(u)=\left(\frac{\pi-2}{\pi}\right)\sigma_u^2$.

The density of v_i is given as

$$f(v_i) = \frac{1}{\sigma_v\sqrt{2\pi}} \exp\left(\frac{-v_i^2}{2\sigma_v^2}\right) \quad (3.10)$$

Then the joint density function is:

$$f(u_i, v_i) = f(u_i).f(v_i) = \frac{2}{2\pi\,\sigma_u\sigma_v} exp\left(\frac{-u_i^2}{2\sigma_u^2} - \frac{v_i^2}{2\sigma_v^2}\right) \quad (3.11)$$

To obtain the density of the composed error term $\varepsilon_i = v_i - u_i$, first obtain the joint density of $f(u_i, \varepsilon_i)$ as

$$f(u_i, \varepsilon_i) = \frac{2}{2\pi\,\sigma_u\sigma_v} exp\left(\frac{-u_i^2}{2\sigma_u^2} - \frac{(v_i-\varepsilon_i)^2}{2\sigma_v^2}\right) \quad (3.12)$$

Then the marginal density function of ε_i is then obtained by integrating u_i out of $f(u_i, \varepsilon_i)$ which yields:

$$\text{f}(\varepsilon_i) = \int_0^\infty f(u_i, \varepsilon_i)du_i = \frac{2}{\sqrt{2\pi}\,\sigma}\left[1 - \Phi\left(\frac{-\varepsilon_i\lambda}{\sigma}\right)\right] exp\left(\frac{\varepsilon_i^2}{2\sigma^2}\right) \quad (3.13)$$

A convenient parameterization which also produces a useful interpretation is

$\sigma^2 = \sigma_u^2 + \sigma_v^2$, $= \frac{\sigma_u}{\sigma_v}$, then the density function of the composite error term ε_i also given as

$\text{f}(\varepsilon_i) = \frac{2}{\sigma\sqrt{2\pi}}\phi\left(\frac{\varepsilon_i}{\sigma}\right)\left[\Phi\left(\frac{-\varepsilon_i\lambda}{\sigma}\right)\right]$ where; $\phi(.)$ standard normal density and $\Phi(.)$ the standard normal CDF. This density function of ε_i is skewed in the negative direction. The constructed parameter $\lambda = \frac{\sigma_u}{\sigma_v}$ characterizes the distribution. If $\lambda \to +\infty$, the deterministic frontier results. If $\lambda \to 0$, the implication is that there is no inefficiency in the disturbance, and the model can be efficiently estimated by ordinary least squares.

The likelihood function of the sample for the composite error is then, by independence, the product of the density functions of the individual observations.

$$L(\varepsilon|\beta, \lambda, \sigma) = \prod_{i=1}^{n} f(\varepsilon_i) \quad (3.14)$$

And then taking log of the likelihood function yields the log-likelihood equation given as:

$$\text{Ln L}\,(\varepsilon|\beta, \sigma) = \text{n ln}\left(\frac{\sqrt{2}}{\sqrt{\pi}}\right) + \text{nln}\left(\frac{1}{\sigma}\right) + \sum_{i=1}^{n} ln[1 - \Phi(\varepsilon\lambda\sigma^{-1})] - \frac{1}{2\sigma^2}\sum_{i=1}^{n}\varepsilon_i^2 \quad (3.15)$$

Using $\varepsilon_i = ln(y_i) - \beta\ln(x_i)$

According to Battese and Corra (1977), the log likelihood function of the model is also specified as:

$$LnL(\varepsilon|\beta,\lambda,\sigma) = \frac{-n}{2}\left(\ln\left(\frac{\pi}{2}\right) + ln\sigma^2\right) + \sum_{i=1}^{n} \ln[1 - \Phi(\frac{\varepsilon_i\sqrt{\gamma}}{\sigma^2}\sqrt{\frac{\gamma}{1-\gamma}})] - \frac{1}{2\sigma^2}\sum_{i=1}^{n} \varepsilon_i^{\,2} \qquad (3.16)$$

With the parameterization $\gamma = \frac{\sigma_u^{\,2}}{\sigma^2} = \gamma = \frac{\sigma_u^{\,2}}{\sigma_u^{\,2}+\sigma_v^{\,2}}$ bounded between zero and one. It is the fraction of the variance of the inefficiency to the total variance.

The maximization of the above log likelihood function with respect to the parameters β and $\boldsymbol{\sigma^2}$ and solving the resulting partial derivatives simultaneously, produces the maximum likelihood estimates of the parameters $\widehat{\beta},\ \widehat{\sigma}^2 = \widehat{\sigma}_v^{\,2} + \widehat{\sigma}_u^{\,2}$, and $\widehat{\lambda} = \frac{\widehat{\sigma}_u}{\widehat{\sigma}_v}$.

The estimation of the stochastic production frontier function may be viewed as a variance decomposition model, which can be expressed as:

$$\sigma^2 = \sigma_v^{\,2} + \sigma_u^{\,2}$$

$$\lambda = \frac{\sigma_u}{\sigma_v} \qquad (3.17)$$

$$\gamma = \frac{\sigma_u^{\,2}}{\sigma^2} = \frac{\sigma_u^{\,2}}{\sigma_v^{\,2}+\sigma_u^{\,2}} = \frac{\lambda^2}{1+\lambda^2} \quad , \quad 0 \leq \gamma \leq 1$$

Where;

γ −Parameter has a value between 0 and 1. A value of γ of zero indicates that the deviations from the frontier are due entirely to noise, while a value of one would indicate that all deviations are due to technical inefficiency.

$\sigma_u^{\,2}$ −is the variance parameter that denotes deviation from the frontier due to inefficiency;

$\sigma_v^{\,2}$ − is the variance parameter that denotes deviation from the frontier due to noise

σ^2 −is the variance parameter that denotes the total deviation from the frontier.

The conditional distribution of u_i given ε_i could be exploited to get estimates of producer specific inefficiency. This was first demonstrating by Jondrow *et al*. (1982). As it is impossible to obtain for each individual producer estimates for u_i and v_i, the inefficiency ratio TE_i is obtained as the exponential conditional expectation of $-u_i$ given the composed error term ε_i:

$$\widehat{TE}_i = e^{E(-u_i/\varepsilon_i)} \qquad (3.18)$$

The conditional density of u given ε

$$f(u|\varepsilon) = \frac{f(u,\varepsilon)}{f(\varepsilon)} = \frac{1}{\sigma^*\sqrt{2\pi}} exp\left(\frac{-(u-\mu^*)^2}{2\sigma^{*2}}\right)\left[(1-\Phi(-\frac{\mu^*}{\sigma^*})\right]^{-1} \quad (3.19)$$

Hence, the distribution of u conditional on $\varepsilon\ is\ N^+(\mu^*, \sigma^*)$

Where, $\mu^* = -\frac{\varepsilon\sigma_u{}^2}{\sigma^2} = -\varepsilon\gamma$

$$\sigma^{*2} = \frac{\sigma_u{}^2\sigma_v{}^2}{\sigma^2} = \frac{\sigma^2\sigma_u{}^2(\sigma^2-\sigma_v{}^2)}{\sigma^2\sigma^2} = \sigma^2\gamma(-\gamma)$$

When $\gamma = \frac{\sigma_u{}^2}{\sigma^2}$ the fraction of the variance of the inefficiency to the total variance.

Having obtained the distribution of u/ε, the expected value $E(u|\varepsilon)$ can be used as a point estimator for u_i (Jondrow *et al*.,1982).

In the prediction of producer level technical efficiencies, Battese and Coelli (1995) as pointed out that the best predictor of exp $(-u_i)$ is obtained by:

$$\widehat{TE}_i = \text{E}[\exp(-u_i)/\varepsilon_i] = \frac{1-\Phi(\sigma_A+\gamma\varepsilon_i/\sigma_A)}{1-\Phi(\gamma\varepsilon_i/\sigma_A)} exp(\gamma\varepsilon_i + \sigma_u{}^2/2) \quad (3.20)$$

Where: $\sigma_A = \sqrt{\gamma(1-\gamma)\sigma_u{}^2}$; $\varepsilon_i = ln(y_i) - ln(x_i)\beta\ and\ \Phi(.)$ is the standard normal CDF.

3.4.1.2. Goodness of fit for the model

The compound disturbance in the stochastic frontier model, while asymmetrically distributed, is, for most choices of the disturbance distribution. In this study, composite error in stochastic frontier model assumes normal-half normal (normal distribution for noise and half normal distribution for inefficiency). In the case of normal-half normal composite error in stochastic frontier model the density function of composite error can be derived by multiplying the normal and half normal density assuming independence of the noise and inefficiency component shown above. This density of composite error is skewed in the negative direction. This helps to check whether the given composite error in stochastic frontier model is normal-half normal or not. In other words its density skewed in the negative direction helps as a graphical test of normal-half normal composite error in stochastic frontier model.

The absence or the presence of technical inefficiency in a given data can easily be tested using the generalized ratio test. The generalized-ratio test requires the estimation of the model under both the null and alternative hypotheses. The existence of inefficiency can be tested using γ parameter and can be interpreted as the percentage of the variation in productivity that is due to technical inefficiency. Likewise, the significance of γ indicate whether the conventional average production function adequately represent the data or not. This also tested by using σ_u. It should be noted that technical inefficiency given above can only be estimated if the technical inefficiency effects, u_i's exist. It is, therefore, of interest to test the following hypotheses:

H_0: σ_u=0, the null hypothesis specifies that inefficiencies are absent from the model at every level;

H_0: $\delta_1 = \delta_2 = ... = \delta_k$ =0, the null hypothesis specifies that the inefficiency effects are not a linear function of each of the inefficiency factors. This test is similar to testing H_0: $\gamma = 0$.

H_0: $\beta_1 = \cdots = \beta_k = 0$, for the goodness of fit test for stochastic frontier model.

Under the null hypothesis, H_0: γ =0; the stochastic frontier model reduces to a traditional average response function, without the technical inefficiency effect u_i. The null hypotheses can be tested using the generalized likelihood ratio statistic, λ , given by:

$$LR = \lambda = -2[LLH_0 - LLH_1] \quad (3.21)$$

Where, LLH_0 and LLH_1 denote the values of the log likelihood function under the null H_0 and alternative H_1 hypotheses, respectively. This generalized likelihood-ratio test, LR, has asymptotic distribution, which is a mixture of X^2 distribution, namely $\frac{1}{2} {X_0}^2 + \frac{1}{2} {X_1}^2$ Coelli (1995).

Multicollinearity: The problem occurs when the explanatory variables are very highly correlated with each other. In the model, $Y = X\beta + \varepsilon$ multicollinearity means **X** contains two or more highly correlated columns. The easiest way to measure the extent of multicollinearity is simply to look at the matrix of correlations between the individual variables.

Variance inflation factor (VIF) -Variance inflation factors are calculated as (VIF= $\frac{1}{1-{R_i}^2}$), where ${R_i}^2$ is the squared multiple correlation coefficient between x_i and the remaining explanatory variables. If VIF ϵ [0, 10], then there is no problem in the estimated component of $\hat{\beta}$. On the other hand if any of VIF's exceeds 10, then this is an indication that the associated regression coefficients are poorly estimated due to multicollinearity.

3.4.2. Logistic regression model

In this study in addition to stochastic frontier model, logistic regression model is used to analyze poverty status of the household. What distinguishes a logistic regression model from the linear regression model is that the dependent variable in logistic regression is binary or dichotomous. The dependent variable in this case is poverty status. It is dichotomous, poor and non-poor by considering annual income of the household. The income of the household was computed by multiplying each agricultural product with their average market price and adds with income that the household got from non-agricultural sources. By using the international standard of poverty line set by World Bank (1.25 dollar per day for one individual), if the income of the household is below the standard, then the household is considered as poor if not non-poor.

Binomial (or binary) logistic regression is a form of regression, which is used when the dependent variable is dichotomous, such as presence/absence or success/failure and the independent variables are of any type. Logistic regression can be used to predict a dependent variable on the basis of continuous and/or categorical independent variables and to determine the percent of variance in the dependent variable explained by the independent variables; to rank the relative importance of the independent variables; to assess interaction effects; and to understand the impact of the covariate control variables Maddala (1997).

The dependent variable in logistic regression is usually dichotomous, that is, the dependent variable can take the value 1 with a probability of success π_i, or the value 0 with a probability of failure $1 - \pi_i$. This type of variable is called a Bernoulli (or binary) variable Green(2000).

Binary logistic regression model is used to investigate the effect of predictors on the probability of being non-poor/poor defined as follows: The dependent variable is given as:

$$Y_i = \begin{cases} 1, \text{the i}^{\text{th}} \text{ household is poor} \\ 0, \text{the i}^{\text{th}} \text{ household is non poor} \end{cases} \qquad \text{i= 1, 2, . . . , n}$$

The relationship between the dependent variable and the independent variables are not linear, the model for π is fitted by using the transformation of π called the logarithms of the odds of the success outcome. The odds are defined as the probability of a success outcome divided by the probability of a failure outcome. The formula is given by:

$$Odds = \frac{\text{Pr (success)}}{Pr(failure\ )} = \frac{\text{Pr (success)}}{1-\text{Pr (success)}} = \frac{\pi}{1-\pi}$$

The value of π is within interval (0, 1) and the odds can take values with the interval $(0, \infty)$.

Writing in terms of estimated sample proportion (p): $Odds = \frac{p}{1-p}$

The odds are non-negative and interpreted as number of times a success is more likely than a failure. The logistic regression model is written in terms of the logarithms of the odds of the success outcome called logit. The logit of the unknown binomial probabilities (π) are modeled as a linear function of the independent variables (X_i).

The logistic function is given by:

$$\hat{\pi}_i = \frac{e^u}{1+e^u} \tag{3.22}$$

Where:

$\hat{\pi}_i$ -is the estimated probability that the ith case is in a category and U is the regular linear equation given as:

$$u = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + .\ \ .\ \ . + \beta_k X_k$$

Where:

β_0- Constant term

β_j*'s* -are coefficients of independent variables (parameters), j= 1, 2, 3, . . . , k

Poverty status (Dependent variable) - Dummy variable as success and failure (0=non-poor and 1=poor) based on per-capita income of the household in 2014/2015 (2007E.C).

X_{ij} ’s- are explanatory variables that determines the poverty status of the households

Rewriting equation 3.20 as follows:

$$\hat{\pi}_i = \frac{e^{\beta_0+\beta_1 X_{i1}+\beta_2 X_{i2}+. \ . \ .+\beta_k X_{ik}}}{1+e^{\beta_0+\beta_1 X_{i1}+\beta_2 X_{i2}+. \ . \ .+\beta_k X_{ik}}} \qquad (3.23)$$

This means that the probability of a success (Y=1) given the predictor variable x is a nonlinear function. Writing the logistic regression in terms of odds ratio for success is:

$$\frac{\hat{\pi}}{1-\hat{\pi}} = \frac{e^{\beta_0+\beta_1 X_1+\beta_2 X_2+. \ . \ .+\beta_k X_k}}{1+e^{\beta_0+\beta_1 X_1+\beta_2 X_2+. \ . \ .+\beta_k X_k}} \div (1 - \frac{e^{\beta_0+\beta_1 X_1+\beta_2 X_2+. \ . \ .+\beta_k X_k}}{1+e^{\beta_0+\beta_1 X_1+\beta_2 X_2+. \ . \ .+\beta_k X_k}})$$

$$\frac{\hat{\pi}}{1-\hat{\pi}} = \frac{e^u}{1+e^u} \div (1 - \frac{e^u}{1+e^u}) = \frac{e^u}{1+e^u} \div \frac{1(1+e^u)-e^u}{1+e^u} = \frac{e^u}{1+e^u} \div \frac{1}{1+e^u}$$

$$\frac{\hat{\pi}}{1-\hat{\pi}} = \frac{e^u}{1+e^u} \times \frac{1+e^u}{1} = e^u$$

Where: $u = \beta_0 + \beta_1 X_1 + \beta_2 X_2 +. \ . \ .+\beta_k X_k$

Then, we obtained the following equation:

$$\frac{\hat{\pi}}{1-\hat{\pi}} = e^{\beta_0+\beta_1 X_1+\beta_2 X_2+. \ . \ .+\beta_k X_k} \qquad (3.24)$$

The logistic regression model is written in terms of the log of the odds called logit, taking natural log of both sides in (3.22), we have:

$$ln\,(\frac{\hat{\pi}}{1-\hat{\pi}}) = ln\,(e^{\beta_0+\beta_1 X_1+\beta_2 X_2+. \ . \ .+\beta_k X_k})$$

$$ln(\frac{\hat{\pi}}{1-\hat{\pi}}) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 +. \ . \ .+\beta_k X_k$$

$$Logit(\hat{\pi}) = ln\left(\frac{\hat{\pi}}{1-\hat{\pi}}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 +. \ . \ .+\beta_k X_k \qquad (3.25)$$

In terms of estimate sample proportion (p), the logistic regression model in terms of logit transformation of the odds is given as:

$$Logit(p) = ln(\frac{p}{1-p}) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 +. \ . \ .+\beta_k X_k$$

Where, β_0 is the constant of the equation and, $\beta_j^{'}s$ $(j = 1,2,\dots,k)$ are the coefficients of the predictor variables.

The coefficients were interpreted as the change in the log-odds associated with a one unit change in the corresponding independent variable or the odd increases multiplicatively by e^{β} for every one unit change increase in x. The regression slopes, is interpreted as is that a unit change in $X_1, X_2, \ldots, X_k$ increases the log odds (logit) of Y by $\beta_1, \beta_2, \beta_3, \ldots, \beta_k$, on average respectively. In other words, as X_i increases by one unit the odds that $Y = 1$ changes by a multiplicative factor e^{β_i}.

Finally, the model $\frac{\hat{\pi}}{1-\hat{\pi}} = e^{\beta_0+\beta_1X_1+\beta_2X_2+...+\beta_kX_k}$ can also be written on the probability scale, as $\hat{\pi} = \frac{e^{\beta_0+\beta_1X_1+\beta_2X_2+...+\beta_kX_k}}{1+e^{\beta_0+\beta_1X_1+\beta_2X_2+...+\beta_kX_k}}$

Thus, we can predict the probability ($\hat{\pi}$) of the dependent variable for any given independent variable. The ratio of success to failure, $\frac{\hat{\pi}}{1-\hat{\pi}}$, is called the odds of success. The dependence of the success probability on the explanatory variables, the probability scale is transformed from the range (0, 1) to ($-\infty$, ∞). This transformation ensures that the fitted success probabilities lie between 0 and 1.

A model was constructed that includes all predictor variables that are useful in predicting the response variable. Several different options were available during model construction. Variables can be entered into the model in the order specified by the researcher or logistic regression can test the fit of the model after each coefficient is added or deleted, called stepwise regression. The fit of the model was tested after the elimination of each variable to ensure that the model still adequately fits the data. When no more variables can be eliminated from the model, the analysis was completed.

3.4.2.1. Method of estimation for the logistic regression model

The dependent variable, poverty, is unobserved and the resulting model is nonlinear, it cannot be estimated by using OLS so maximum likelihood estimation (MLE) is used. The logistic regression model is nonlinear an iterative algorithm method necessary for parameter estimation. Let p be the probability of success and it is equivalent to the probability that the response variable assumes value one. Then P(Y=1)= $\frac{1}{1+e^{-X'\beta}}$ each observation (response) can be considered as an outcome of a Bernoulli trial. Hence for the ith observation Y_i the Bernoulli distribution is:

$$P(Y=y) = p^{y_i}\,(1-p)^{1-y_i} \tag{3.26}$$

Then the likelihood function is the joint probability distribution of all *n* observation is

$$L = \prod_{i=1}^{n} p^{y_i}\,(1-p)^{1-y_i} = \prod_{i=1}^{n}\left(\frac{1}{1+e^{-X'\beta}}\right)^{y_i}\left(\frac{e^{-X'\beta}}{1+e^{-X'\beta}}\right)^{1-y_i} \tag{3.27}$$

Taking the natural logarithm of both sides yields

$$lnL = \sum_{i=1}^{n} y_i\, ln\left(\frac{1}{1+e^{-X'\beta}}\right) + \sum_{i=1}^{n}(1-y_i)\, ln\left(\frac{e^{-X'\beta}}{1+e^{-X'}}\right) \tag{3.28}$$

Hence, through maximization of the above log-likelihood function, the parameter vector β was estimated. But the equation is nonlinear in β, and as a result the estimates do not have a closed form expression. Therefore, β were obtained by maximizing using a numerical iterative method Agresti (1996).

3.4.2.2. Assessing the goodness of fit for logistic regression model

The likelihood ratio criterion (deviance analysis): The log likelihood-ratio test uses the ratio of the maximized value of the likelihood function for the intercept only model L_0 over the maximized value of the likelihood function for the full model L_1. Log likelihood is the basis for tests of a logistic model. The deviance D is defined as:

$$D=2\log\left(\frac{L_0}{L_1}\right) = -2[log(L_0) - log(L_1)] = -2[LL_0 - LL_1] \tag{3.29}$$

Where, $LL_0$is the log likelihood value of the model which has the intercept term only and LL_1 is the log likelihood value of the full model. The likelihood ratio statistic has a chi-square distribution and it tests the null hypothesis of all logistic regression coefficients except the constant are zero. The degrees of freedom are obtained by differencing the number of parameters in both models. It compared with chi-square value at the difference between degree of freedom of both model.

Hosmer-Lemeshow Test: This is used to test whether the model fit the data or not. The test divides subjects into g groups mostly deciles based on predicted probabilities, and then computes a chi square from observed and expected frequencies. Then a probability (p) value is computed from the chi-square distribution with 8 degrees of freedom to test the fit of the logistic model. The Hosmer-Lemeshow test statistic is given by

$$\hat{C} = \sum_{k=1}^{10} \frac{(O_k - E_k)^2}{V_k} \qquad (3.30)$$

Where, O_k is the observed number of events in the k^th^ group, E_k is expected number of events in the k^th^ group, and V_k is a variance correction factor for the k^th^ group. If the observed number of events differs from what is expected by the model, the statistic $\hat{C}$ will be large and there will be evidence against the null hypothesis. This statistic has an approximate Chi-Squared distribution with (g – 2) degrees of freedom Hosmer and Lemeshow (1989).

The Wald test: A Wald test is used to test the statistical significance of each coefficient (β_i) in the model. The test statistic is a chi-square statistic with a desirable outcome of non-significance, indicating that the model prediction does not significantly differ from the observed**.**

The hypothesis tested is:

$H_0{:}\beta_j = 0 \quad vs\ H_1{:}\beta_j \neq 0\ , j = 1,2,\ldots,k$ at α level of significance. The Wald test statistics, Wald, for this hypothesis:

$$\text{Wald} = \frac{\hat{\beta}_j^{\ 2}}{\left(SE(\hat{\beta}_j)\right)^2} = \frac{\hat{\beta}_j^{\ 2}}{Var\,(\hat{\beta}_j)} \sim {\chi^2}_{(1)} \qquad (3.31)$$

Where, $\hat{\beta}_j^{\ 2}$ is the square of the estimated regression coefficient and $Var(\hat{\beta}_j)$ is the variance of $\hat{\beta}_j$.

The Wald test is one of a number of ways of testing whether the parameters associated with a group of explanatory variables are zero. If the Wald test is significant for a particular explanatory variable then the parameters associated with these variables are not zero so that the variables should be included in the model otherwise the explanatory variables can be omitted from the model Agresti (1996).

3.5. Definition and Measurement of Variables

In order to explain determinants of crop productivity, inefficiency and poverty, categorical and continuous variables are identified based on economic theory and findings of empirical studies.

All inputs and outputs were transformed to their corresponding log values in estimating the Cobb Douglas production function. The variables that are used in the production functions, determinants of inefficiency and determinants of poverty are here identified and defined briefly as follows.

Dependent variables

Crop productivity (YIELD): yield, which is the dependent variable in the estimation of production function for major crops productivity separately and which is measured in kilogram per hectare (kg/ha). This variable is continuous. In this study crop represents major crops produced in the study area (*teff*, wheat, bean, barley and sorgum). The dependent variable is considered in the analysis for each crop individually.

Poverty status of the household (POVERTY): The dependent variable for the logistic regression model is poverty status. The household is considered as poor if the income per individual per day is less than 1.25 dollar and non-poor otherwise. It is dummy variable that takes the value 1 for poor and 0 for non-poor.

Independent variables

Seed (SEED): it is one of the basic inputs for crop production. It refers to the amount of seed used in kilogram per hectare for the production of the respective crops. Susan *et al. (*2014) and Wassie (2014) confirmed that seed has positive and significant effect on crop productivity. Therefore, in this study seed rate was expected to influence crop productivity positively.

Fertilizer (FERT): the amount of fertilizer consumption in kg per hectare by the farmer for the specific crop productivity of 2014/2015 production season. It is continuous. The amount of fertilizer used has significant and positive effect on crop productivity (Ukoha *et al*., 2010; Akintayo, 2011). The expected effect of fertilizer on crop productivity is positive.

Oxen-pair days for ploughing (OXEN): refers to the number of oxen-pair days the household used for ploughing purpose. For the analysis of productivity oxen-pair days used per hectare for ploughing purpose have positive effect on productivity (Zewdu *et al*., 2012; Solomon, 2014). Therefore, in this study oxen-pair days was hypothesized to have positive effect on crop productivity.

Labor force (LABOR): This input captures family and hired labor used for different agronomic practices of crop production. Therefore, the human labor input is expressed in terms of total labor force employed to perform land preparation, planting, input application, cultivation, harvesting, and threshing for the production of a particular crop. In the analysis, total labor force employed per hectare was used for the production of a specified crop. Labor force employed has positive and significant effect on crop productivity (Larry *et al.*, 2011; Endrias *et al*., 2013; Solomon, 2014). Therefore, in this study labor force employed was expected to influence crop productivity positively.

Sex of household heads (SEX): It is a dummy variable that takes the value 1 for male and 0 for female. Male headed households have better opportunity to engage in farming activities than female headed households. The probable reason is that female's major activities are mostly at home not denying their active labor contribution to agriculture, due to cultural influence. Crop productivity was better for male headed household (Ukoha *et al*. 2010; Akintayo, 2011). The study suggested by Endrias *et al.* (2013) also confirmed that male headed households were better in efficiency for productivity. Therefore, positive relation was expected between male household head and productivity and also better in technical efficiency.

Age of household head (AGE): Age is a continuous variable and it is the age of household heads in years. When the age of household head increase their ability to engage in different agricultural productivity activities decrease (Adugna, 2005; Gebrehiwot and Fekadu, 2012). On the other hand, Khatun and Roy (2012) has found that age have a significant and positive influence on farmers' productivity. The reason is that experience increases with age; consequently, experienced persons have more prospects of adopting new technologies. The study by Endrias *et al.* (2013**)** and Wassie (2014) confirmed that age has negative influence on technical efficiency. In this study it is hypothesized that the age of household head is expected to have negative influence on technical efficiency.

Educational level of household head (EDUCATION): Education refers to the education level of household head in years. Many studies have revealed that the level of education (years of schooling) helps farmers to use production information efficiently, as a more educated person acquires more information and, to that extent, is a better producer (Ajibefun *et al*., 2006; Idjesa, 2007). Literate people have better probability for being better off by using new agricultural technologies. The study conducted by Endrias *et al.* (2013**)** and Wassie (2014) also suggested that education has positive influence on technical efficiency for crop production. This variable is thus expected to have a positive influence on technical efficiency.

Health problem (HEALTH): It assumes as dummy take the value 1 if there is severe illness of the member of household and 0 otherwise in the last 12 months (using 2007E.C as reference). The health status of the household members affected by different unexpected things may determine the labor allocation of the household as well as the income. Among these, the illness of the husband or/and the wife is one. It has adverse effect in labor allocation and negatively affects agricultural productivity Ukoha *et al*. (2013). In this study the expected influence of health status on technical efficiency was negative.

Land quality (LQUALITY): it refers to the quality of soil in the area or fertility of the soil for the cultivated land on which a particular crop is produced. Farmers were asked to rate the relative fertility status of their plots based on their perception. It is categorical variable take the value 0 for infertile, 1 for medium and 2 for fertile based on the farmer's perception about the plot cultivated. Kebede (2011) concludes that soil fertility increases productivity. The study by Wassie (2014) suggested that the fertility of land has positive influence for technical efficiency. Therefore, land fertility is expected to have positive effect on technical efficiency in this study.

Number of extension contact (EXTENSION): Extension contact refers to the opportunities that farmers are getting different services like advice, training, demonstration and agricultural inputs like fertilizer and seed from agricultural bureau through extension workers in the year 2014/15 production season. It assumes the number of contact the farmer has with the extension worker. According to Adugna (2008), there is a significance relationship between extension contact and wealth status. If the wealth status is high households have a chance to accumulate more capital and thereby most likely to invest in more agricultural activities. Agricultural productivity is increased by contact with extension agents (Ukoha *et al*., 2010). In addition to this, many studies confirm that extension contact has positive effect on technical efficiency of the farmer (Endrias *et al*., 2013; Susan *et al*., 2014; Wassie, 2014). In this study, extension contact is expected to have positive effect on technical efficiency.

Credit service (CREDIT): It is a dummy variable that takes the value of 1 if there is utilization of credit service by rural farm households and 0 otherwise. The actual borrowing from institutional as well as non-institutional sources is considered as the opportunity for better agricultural productivity. Utilization of credit has positive effect on productivity Shehu *et al*. (2010). The study by Susan *et al*. (2014) confirmed that utilization of credit has a positive effect on technical efficiency. Therefore, in this study utilization of credit is expected to have a positive effect on the technical efficiency.

Access to ICT (ICT): It refers to the farmers' access to use radio or mobile that helped them to get production and market related information. It is a dummy variable which assume the value 1 for those having the access and 0 for those not have access. Using radio or mobile to obtain agricultural and market related information improves agricultural productivity, either by improving farmer decision making or by improving input delivery Lorenzo and Michael

(2013). In this study, it is expected that those farmers who have access to ICT are technically efficiency as compared to those who do not have access.

Family size (FS): It refers to the number of person (family member) in the household. It is the sum of labor force and non-labor force in the household. It is the dominant source of labor force. The study conducted by Endrias *et al.* (2013**)** confirmed that family size has negative influence on technical efficiency of farmers**.** On the other hand, the study conducted by Larry *et al.* (2011) suggested that family size has positive influence on technical efficiency. In this study, family size is expected to have positive effect on technical efficiency.

Agro-chemicals (AGC): It refers to pesticide and herbicide that are used to agricultural productivity purpose. It is dummy take value (1=agro-chemical user and 0= not user). According to David *et al*. (2009) optimal usage of such agro-chemicals improve agricultural productivity. Therefore, in this study positive relation is expected between agrochemical usage and technical efficiency.

Dependency ratio (DPNR): it refers to the ratio of dependent age group (non-labor force) and working age group (labor force) in the household. It assumes a continuous value. Large value of it had negative impact on agricultural productivity. The shortage of labor force in the household negatively affects agricultural productivity (Shehu *et al*., 2010; Akintayo, 2011). Negative relation is expected between dependency ratio and agricultural productivity. The chance of a household being poor increased due to increase in household size Amjad and Maqbool (2008). Hence, it was hypothesized that dependency ratio and poverty to be positively related.

Household home distance to main market (DISTANCE): market distance refers to the amount of kilometer that the household need to travel to reach main market in the surrounding area and it is a continuous. It significantly affects agricultural productivity. Distance from the main market negatively affect income and the benefit the household obtained from their agricultural products like vegetable by affecting productivity and profitability Bongiwe *et al*. (2013). In this study, positive relation was expected between distance and poverty.

Irrigation (IRG): It is a dummy variable and it takes 1 for the household who uses irrigation, 0 otherwise. Irrigation in this context refers to having access to cultivating crops by using irrigation water. Irrigation opportunities make multiple cropping possible which will create alternative agricultural outputs and improves agricultural productivity Ayele (2011). This leads to increase the income for the household. In this study, it was expected to have negative relation between irrigation user and poverty.

Natural Risks (RISK): risk means the presence of heavy rains, crop and animal disease etc. that affect productivity of rural households' farm activities and influence the income of the household. It is a dummy variable which takes 1 for presence of risks, 0 otherwise. Erratic rain fall and water scarcity or the existence the risk prevents the rural household to improve productivity Khatune and Roy (2012). If farmers' income from crop and animal production is affected by different risks their asset accumulation and income are affected negatively. In this study, it was expected to have positive effect of risk on poverty.

Non-labor income (NLI): this includes all income as gift, remittance, donation/ aid, other transfer and compensation. Consider it as dummy variable and takes the value 1 for the household who get non- labor income, 0 otherwise. Non-labor income has positive effect on agricultural productivity and helps to reduce poverty Mapula *et al*. (2011). In this study, negative relation was expected between non-labor income and poverty.

Livestock holding (excluding oxen): Livestock refers to the number of livestock in TLU the household owned. It assumes continuous value. Those households having large number of livestock have more probability to have good living standard. Livestock were significantly related to the probability of being poor Amjad and Maqbool (2008). In this study, significant and negative relation was expected between livestock holding in TLU and poverty of the household.

Non or Off-farm activity: It is the participation of the household member in non or off farm activities such as daily labor, trade, selling and local drinks, selling wood, etc. It is a dummy variable that takes a value 1 if the household is participant in non or off farm activities and 0 otherwise. Most farmers commonly generate their income from their farm. However, they occasionally look for other income source by participating in non- and off- farm activities to purchase clothes, inputs, food and food related items Yilma (2005). The importance of rural non- and off-farm activities to income diversification and poverty reduction has been well recognized. Evidence shows that the developments of rural non and off-farm activities have increased rural household income and contributed to rural development and used to reduce poverty Ye *et al*. (2011). Therefore, it was expected that off-farm activity and poverty have a negative relationship.

Place of residence (PR): This refers to whether the household place of residence in midland or low land. It has two categories (dummy) and takes the value 1 for those who live in midland and 0 for those who live in low land. Residential place were significantly related to the probability of being poor Amjad and Maqbool (2008).

4. RESULTS AND DISCUSSION

4.1. Descriptive Results

The results in this study were based on cross-sectional data collected from 207 sample households selected from Menz Keya Gebriel district in North Shewa zone. The data collected were production and productivity of crops, income of the households and sources of income that are necessary for the study. The household cultivate many crops but this study focuses on five crops depending on plot size, importance, and the number of households cultivating the crops. Among the sample households, 204, 187, 172, 115 and 80 were grow *teff*, wheat, bean, barley, and sorgum, respectively. This chapter presents the results and discussion part of the study. The first section comprises the results of descriptive statistics. The second section deals with econometrics model results.

4.1.1. Demographic and socio-economic characteristics

Table 1 presents demographic and socio economic characteristics of sample households (sex of the household head, marital status of the household head, health status of the household member and place of residence of the household). Female headed households included in the study area were accounted 14.01% (7 non-poor and 22 poor) of the sampled households and male headed households accounted 85.99% (63 were non-poor and 115 poor). These shows female headed households are very small compared to male headed households.

The marital status of the household head indicates that from the sample households, 2.4%, 81.6%, 8.2% and 7.7% were single, married, divorced and widowed, respectively. The descriptive result also shows out of 207 sample households 28.5% of them faced severe health problem (16 were non-poor and 43 were poor) and the rest 71.5% of them did not face severe health problem (54 were non-poor and 94 were poor) in the household member. Among the sample households, 62.8% of the households' place of residence is midland (37 of them were non-poor and 93 of them were poor) and the remaining households' place of residence is lowland (33 of them were non-poor and 44 poor households) (Table 1).

Table 1: Summaries of demographic characteristics of the households with poverty status

Variable	Category	Poverty status		Frequency	Percentage
		Non-poor	Poor		
Sex of the household head	Female (0)	7	22	29	14.01
	Male (1)	63	115	178	85.99
Marital status of the household head	Single (0)	2	3	5	2.4
	Married (1)	57	112	169	81.6
	Divorced (2)	5	12	17	8.2
	Widowed (3)	6	10	16	7.7
Health status of the family member	No sever illness (0)	54	94	148	71.50
	Sever illness (1)	16	43	59	28.50
Place of residence	Low land (0)	33	44	77	37.20
	mid land (1)	37	93	130	62.80

Source: Own survey data (2016)

4.1.2. Institutional characteristics

Table 2 present the descriptive statistics results of the variables credit, ICT, irrigation, non or off-farm activity, natural risks, non-labor income, agro-chemical, improved seed, and poverty status of the sample households.

The descriptive statistics results of credit indicate that about 58.94% of households used credit service (among those user households 39 were non-poor and 83 were poor). The remaining 41.06% of the households not used credit service; this may be to various reasons such as limited access of the service for the intended purpose, misgiving the interest rate and absence of demand for the credit service. Those who have credit service would have the opportunity to access agricultural inputs (such as seed, fertilizer and farming equipments), education and health care services, and buying of agricultural tools and livestock. This helps them to implement agricultural production in a better manner. Similarly, ICT usage of the sample households shows that about 61.84% of the households are ICT users (among users 42 were non-poor and 86 were poor) and the remaining 38.16% (28 of them non-poor and 51 of them were poor) of the households are not user (Table 2).

Table 2 also present irrigation usage of the sample households were 18.84% and 81.16% for user and non-user, respectively. Among 18.84% user households, 29 were non-poor and 10 were poor. Non or off-farm activities participation of households indicate that, out of the total sample households, 65.22% (34 were non-poor and 101 were poor) were not participated and the remaining 34.78% sample households were participated (36 non-poor and 36 poor households) in non or off-farm activities(Table 2).

Among the total sample households 55.56% were not faced with natural risk and the rest 44.44% were faced with the risks. Among the sample households who faced natural risk 21 were non-poor and 71 poor. As the frequencies show, out of the total sample households around half face the problem indicating higher occurrence of the risk in the study area. Similarly, the results indicates that 71.01% of the sample households were not get non-labor income and the remaining 28.99% of the sample households were get non-labor income (Table 2).

Table 2: Summaries of categorical variable related with poverty status of the household

Variable	Category	Poverty status		Frequency	Percentage
		Non-poor	Poor		
Credit	Non-user (0)	31	54	85	41.06
	User (1)	39	83	122	58.94
ICT	Non-user (0)	28	51	79	38.16
	User (1)	42	86	128	61.84
Irrigation	Non-user (0)	41	127	168	81.16
	User (1)	29	10	39	18.84
Non-labor income	No (0)	41	116	147	71.01
	Yes (1)	29	21	60	28.99
Agro-chemical	Non-user(0)	46	73	119	57. 49
	User (1)	24	64	88	42.51
Improved seed	Not used(0)	39	77	116	56.04
	Used (1)	31	60	91	43.96
Non and off-farm activities	Not participate (0)	34	101	135	65.22
	Participate (1)	36	36	72	34.78
Natural risk	No (0)	49	66	115	55.56
	Yes (1)	21	71	92	44.44

Source: Own survey data (2016)

In Table 2 among the total sample households in the study area, 57.49% of them not used agro-chemicals and the remaining 42.51% of them used agro-chemicals in their agricultural production process. Agro-chemical in this case refers herbicide and pesticide. Similarly, out of the total sample households in the study area, 43.93 % of them used improved seed in crop production and the remaining 56.04% were not used improved seed. Lastly, the poverty head count of the sample households were 66.18%, based on 1.25 dollar per day per individual as the poverty line set by World Bank. In this case the income calculation considers all sources of the household income. As the result shows, most of the households (66.18%) were poor based on the sample households (Table 2).

4.1.3. Summary statistics for quantitative variables used in the study

Table 3 presents summary statistics of quantitative variables (output, market value of output, inputs, number of extension contact, age, family size, and income related variable). The descriptive statistics includes mean, variance and standard deviation of the specified variables. It is shown that in the study area the average output of crops the household produced annually was 32.18 quintals with standard deviation of 11.35 quintals. The output of crops includes all crops the household cultivated in the specified production year. As the result also shows, the maximum output obtained by the household was 74 quintals and the minimum 13 quintals with the range of 61 quintals (Table 3). The market value of the output was obtained by changing each output with their respective average market value in birr. The market values of outputs in birr also represent part of income the household obtained from crop production. The large gap between minimum and maximum values of output in quintals (birr) might be due to input usage and efficiency difference of production by the households.

The average annual income for the households, annual income per individual, and daily income per individual were 40289.98, 8324.46, 22.81 birr, respectively. From this result, the average market value of output was 31247.70 birr (income from crop production) indicating that the majority of income of the household is obtained from crop production. This also implies that generation of income from other sources was very low and the living standard of the households is highly dependent on crop production (Table 3).

The average years of education of the household head is 3.79 years with minimum zero (illiterate) and 12 maximum years of education. This might have a potential hindrance effect on effective technology transfer and adoption in the study area. As the summary statistic also shows the average age and farming experience of sample household heads were 51.77 and 28.62 years, respectively (Table 3).

In the study area, the average family size was 5.35 persons per household with standard deviation of 1.89 based on the sample households. The minimum and maximum family size for the household was 2 and 11, respectively. The average number of labor force (15-64 years of age) and non-labor force (age less than 15 and greater than 65) in the household were 3.29 and 2.05, respectively. The average dependency ratio was 0.711, which measures an age-population ratio of those not in the labor force (the dependent members) and those in the labor force (the working members) in the household. This indicates that for every 100 active working persons, there are 71 persons who are not actively working, based on the sample information (Table 3).

In the study area, livestock are also important part of agriculture practices and serve as one source of income next to crop which might also help to improve the living standard of the households. The average number of oxen owned by the household was 2.00 with standard deviation of 0.79. The minimum and maximum numbers of oxen the households own were 1 and 5, respectively (Table 3).

Based on the survey results, the average land holding of the farmers were 3.46 hectares with a standard deviation of 1.26. The minimum and maximum land holding of the household were 1.25 and 7.50 hectares, respectively (Table 3). The results also indicated that the use of fertilizer by the household in the production of all crops had a mean value of 2.66 quintals (266kg) with a standard deviation of 1.81 quintals (180kg) in the specified production year. The minimum and maximum amounts of fertilizer used were 0.5 quintal (50kg) and 8 quintals (800kg), respectively. The average number of contact with extension worker in the specified production season was 3.01 with the minimum and maximum values of 0 and 12, respectively (Table 3).

Table 3: Descriptive statistics for production, income and related variables (n=207)

Variables	Minimum	Maximum	Mean	Std. Dev.
Crop output in quintals	13.00	74.00	32.18	11.35
Output in market value(birr)	10513.5	70708.50	31247.70	11575.03
Annual income in birr	10713.0	92648.50	40289.98	15834.44
Annual income per individual in birr	2385.57	19753.50	8324.46	3925.99
Daily income per individual in birr	6.54	54.12	22.81	10.76
Education of household head	0	12	3.79	2.62
Age of household head	20	90	51.77	13.11
Farming experience	2.0	56.0	28.62	12.20
Family size	2	11	5.35	1.89
Labor force in the household	1	8	3.29	1.28
Dependent members in the household	1	6	2.05	1.32
Dependency ratio	0	3	0.71	.54
Livestock holding in TLU	1.50	19.80	6.27	3.49
Number of oxen owned	1	5	2.00	.79
Land size in hectare	1.25	7.50	3.46	1.26
Fertilizer used in quintal	0.5	8.0	2.66	1.80
Distance to the nearest market in km	1.00	23.00	7.03	5.15
Number of Extension contact	0	12	3.01	2.51

Source: Own survey data (2016)

4.1.4. Summaries of crop yield and rate of main inputs used

In this sub part descriptive statistics about output, yield and rate of basic inputs were discussed for five major crops (*teff*, wheat, bean, barley and sorgum) that the households mostly produced in the study area.

Descriptive statistics of variables used in stochastic frontier model for *teff* productivity and independent variables as the basic input use rates are presented in Table 4 below. All the results represent only for 204 *teff* crop growers in this case. Productivity of crops were computed based on total grain output per unit of land for those who produce the crops and expressed as kg per hectare (kg/ha). The summary result shows that the average productivity of *teff* was 982.32kg/ha with standard deviation of 199.17kg/ha. The minimum and maximum productivity of *teff* were 560 kg/ha and 1400kg/ha, respectively (Table 4).

The inputs used in *teff* production were seed, fertilizer, oxen and labor. The average seed rate per hectare for *tef*f production was about 39.43kg/ha with standard deviation of 2.58. The results also indicated that the use of fertilizer for *teff* production had a mean value of 137.95 kg/ha with standard deviation of 70.90. Labor use for crop production activities (includes ploughing, planting, weeding, harvesting, and threshing) constitutes both family labor and hired ones. The summary result shows that the average number of oxen-pair days per hectare and labor days per hectare were 31.09 and 84.56 with standard deviations of 3.79 and 6.45, respectively (Table 4).

Table 4: Descriptive Statistics of variables for teff crop production (n=204)

Variables	Minimum	Maximum	Mean	Std. Deviation
Output variables				
Teff production(kg)	150.00	2000.00	755.32	347.03
Teff productivity (kg/ha)	560.00	1400.00	982.32	199.17
Input variables				
Seed (kg/ha)	29.00	46.75	39.43	2.58
Fertilizer kg/ha)	16.67	351.58	137.95	70.90
Oxen-pair days/ha	23.54	43.82	31.09	3.79
Labor force (labor-days/ha)	74.56	109.80	84.56	6.45
Land size in hectare	.25	2.00	.79	.39

Source: Own survey data (2016)

The descriptive statistics for variables used in stochastic frontier model for production of wheat as wheat productivity the dependent variable and independent variables as the basic input used in the production process was presented in table 5 below. In this case, all the results were based on 187 wheat growers in the study area.

The descriptive statistics result shows that the average product and productivity of wheat were 1330.35kg and 1239.91kg/ha with standard deviation 617.79kg and 244.82 kg/ha, respectively. The minimum and maximum productivity of wheat were 600 kg/ha and 2000 kg/ha, respectively. Similarly the minimum and maximum production of wheat crop the farmer produced were 440.00 kg and 3750 kg, respectively (Table 5).

The inputs used for wheat production were seed, fertilizer, oxen and labor. The descriptive statistics result shows that the average seed rate per hectare for wheat production was about

173.35kg/ha with standard deviation of 12.25. The results also indicated that the use of fertilizer for wheat production had a mean value of 147.53 kg/ha with standard deviation of 52.76. Moreover, the summary result also shows that the average number of oxen-pair days per hectare and labor days per hectare were 25.10 and 81.42 with standard deviations of 5.52 and 7.05, respectively. Lastly, the average number of land size holding was 1.07 hectare with the standard deviation of 0.44 for wheat crop growers (Table 5).

Table 5: Summary Statistics of variables for wheat crop production (n=187)

Variable	Minimum	Maximum	Mean	Std. Deviation
Output variables				
Wheat production in kg	440.00	3750.00	1330.35	617.79
Productivity of wheat in kg/ha	600.00	2000.00	1239.91	244.82
Input variables				
Seed of wheat in kg/ha	151.24	200.37	173.35	12.25
Fertilizer in kg/ha	50.00	300.00	147.53	52.76
Oxen-pair days/ha	12.50	36.65	25.10	5.52
Labor force(labor-days/ha)	64.57	94.97	81.42	7.05
Land size in hectare	.50	2.50	1.07	.44

Source: Own survey data (2016)

The descriptive statistics result shows that the average product and productivity of bean was 455.05 kg and 979.60 kg/ha with standard deviations of 296.06 kg and 260.86 kg/ha, respectively. The minimum and maximum productivity of bean were 392.53 kg/ha and 1700.00 kg/ha, respectively. Similarly, the minimum and maximum product of bean crop the farmer produced were 150.00 kg and 2125.00 kg, respectively (Table 6).

As given in Table 6, the descriptive statistics result shows that the average seed rate per hectare for bean production was about 182 kg/ha with standard deviation of 4.93. The summary result also shows that the average number of oxen-pair days per hectare and person days per hectare were 15.77 and 61.13 with standard deviations of 2.44 and 4, respectively. Lastly, the average number of land size holding was 0.4622 hectare with the standard deviation of 0.24 for bean crop growers (Table 6).

Table 6: Descriptive Statistics of variables for bean crop production (n=172)

Variables	Minimum	Maximum	Mean	Std. Dev.
Output variables				
Bean production in kg	150.00	2125.00	455.05	296.06
Productivity of bean in kg/ha	392.53	1700.00	979.60	260.86
Input variables				
Seed of bean in kg	175.25	197.53	182.11	4.93
Oxen-pair days/ha	11.55	21.88	15.77	2.44
Labor force (labor-days/ha)	52.50	73.54	61.13	4.42
Land size in hectare	.25	1.50	.4622	.24

Source: Own survey data (2016)

The descriptive statistic result in Table 7 below shows that the average product and productivity of barley were 550.72 kg and 1044.82 kg/ha with standard deviations of 306.73 kg and 269.99 kg/ha, respectively. The minimum and maximum productivity of barley were 600kg/ha and 1700.00 kg/ha, respectively. Similarly, the minimum and maximum production of barley crop was 150.00 and 1992kg, respectively.

Table 7: Summary Statistics of variables for barley crop production (n=115)

Variables	Minimum	Maximum	Mean	Std. Deviation
Output variables				
Barley production in kg	150.00	1992.00	550.72	306.73
Productivity of barley in kg/ha	600.00	1700.00	1044.82	269.99
Input variables				
Seed in kg/ha	178.40	199.45	184.49	5.13
Fertilizer in kg/ha	.0001	200.00	57.28	62.15
Oxen-pair days/ha	12.03	22.89	16.63	2.88
Labor force(labor- days/ha)	29.82	82.85	67.43	9.14
Land size in hectare	.13	1.50	.54	.28

Source: Own survey data (2016)

The main inputs used for barley production were seed, fertilizer, oxen and labor. As given in Table 7, the descriptive statistic result shows that the average seed rate per hectare for barley production was about 184.49 kg/ha with standard deviation of 5.13. The summary result also shows that the average number of oxen-pair days per hectare and labor days per hectare were

16.63 and 67.43 with standard deviations of 2.88 and 9.14, respectively. The average number of land size holding was 0.54 hectare with the standard deviation of 0.28 for barley crop growers of 115 samples (Table 7).

Table 8 below presents descriptive statistics of variables used in stochastic frontier model for production of sorgum by considering productivity of sorgum as the dependent variable and basic input use rate as an independent variables used in the production process. In this case, all the results were based on 80 sorgum growers in the study area. The descriptive statistics result in this table shows that the average product and productivity of sorgum crop were 903.39kg and 953.13 kg/ha with standard deviation of 523.37 kg and 278.72 kg/ha, respectively.

As given in Table 8 below, the descriptive statistics result shows that the average seed rate per hectare for sorgum production was about 11.73 kg/ha with standard deviation of 1.43. The summary result also shows that the average number of oxen-pair days per hectare and labor days per hectare used were 15.96 and 64.62 with standard deviation of 2.42 and 8.78, respectively. Lastly, the average number of land size cultivated was 0.96 hectare with the standard deviation of 0.45 for sorgum crop growers (Table 8).

Table 8: Descriptive Statistics of variables for sorgum crop production (n=80)

Variables	Minimum	Maximum	Mean	Std. Deviation
Sorgum production in kg	150.00	2478.00	903.39	523.37
Productivity of Sorgum in kg/ha	400.00	1752.00	953.13	278.72
Seed of Sorgum in kg/ha	10.00	16.76	11.73	1.43
Oxen-pair days/ha	12.01	22.85	15.96	2.42
Labour force(labor-days/ha)	55.83	91.78	64.62	8.78
Land size in hectare	.25	2.25	.96	.45

Source: Own survey data (2016)

Table 9 present the five crops mean production, productivity and input usage rates and total amount of product in the specified production season in the study area for each major crop. Productivity of crops were computed based on total grain output per unit of land for a particular crop for those who produce the crop and expressed as kg per hectare of land (kg/ha). Based on this, the average productivity of *teff*, wheat, bean, barley and sorgum were 982.32, 1239.91, 981.33, 1044.82 and 953.14 kg/ha, respectively. Moreover, the table also presents the average production the farmer produced for *teff*, wheat, bean, barley and sorgum were 755.32, 1330.35, 458.62, 550.72 and 903.39 kg, respectively.

Among the inputs the average amount of fertilizer used for *teff*, wheat and barley productivity were 138.01, 147.53 and 57.28 kg/ha, respectively (Table 9). In this case, the average amount of fertilizer used for wheat production was high when compared to the others. The average oxen-pair days used for the production of *teff*, wheat, bean, barley and sorgum were 31.09, 25.10, 15.77, 16.63 and 15.97, respectively. Similarly, the average labor force used for the production of *teff*, wheat, bean, barley and sorgum were 84.56, 81.42, 61.08, 67.43 and 64.62 labor-days/ha, respectively (Table 9). The result of the two variable shows on average *teff* production consume the highest oxen pair days and labor force when compared to the production of other crops and bean takes the least value based on the sample information. Lastly, the average land size in hectare cultivated for the production of *teff*, wheat, bean, barley and sorgum were 0.80, 1.07, 0.46, 0.54 and 0.96 hectare respectively (Table 9).

The average productivity (production per hectare) for *teff*, wheat, bean, barley, and sorgum were 982.32, 1239.91, 981.33, 1044.82, and 953.14 kg/ha which are below the national average of 1281, 2029, 1850, 1672, and 2054 kg/ha, respectively CSA (2012). Generally, as the summary shows wheat was the potential and leading crop in terms of average (total) production and average (total) coverage of area cultivated, respectively.

Table 9: Summaries of mean production and productivity of the five crops and input variables

Variables	*Teff*	Wheat	Bean	Barley	Sorgum
Production in kg	755.32	1330.35	458.62	550.72	903.39
Productivity in kg/ha	982.32	1239.91	981.33	1044.82	953.14
Seed in kg/ha	39.43	173.35	182.11	184.49	11.73
Fertilizer in kg/ha	138.01	147.53	-	57.28	-
Oxen-pair days/ha	31.09	25.10	15.77	16.63	15.97
Labor force (labor-days/ha)	84.56	81.42	61.08	67.43	64.62
Land size in hectare	0.80	1.07	0.46	.54	.96
Total land size in hectare	162.89	200.75	79.5	62.26	76.50
Number of observation	204	187	172	115	80

Source: Own survey data (2016)

4.2. Econometrics Model Results

In this sub part, the models used in the analysis were Cobb-Douglas stochastic frontier and logistic regression model for productivity of crops and poverty status of the households, respectively. The stochastic frontier model is used for five crops productivity (*teff*, wheat, bean, barley, and sorgum) by using main input variables and inefficiency variables. In case of logistic regression model, poverty status of the household, specifically income poverty based on their annual income was investigated. The estimation method used for the stochastic frontier and logistic regression model was maximum likelihood method (MLE).

4.2.1. Parameter estimation of SFM and inefficiency effect

The maximum likelihood estimates of the parameters of the stochastic frontier model and inefficiency effects are presented in Tables 10 and 11 below, respectively.

Table 10: Stochastic frontier model results for productivity of five major crops

Variables	$\boldsymbol{\beta's}$	*Teff*	Wheat	Bean	Barley	Sorgum
Constant	β_0	$1.86\ (.49)^{0.000}$	$4.41(.89)^{0.000}$	$5.53(1.52)^{0.000}$	$3.42(.62)^{0.000}$	$2.30(.42)^{0.000}$
lnSeed	β_1	$.302(.092)^{0.001}$	$.0009(.18)^{0.996}$	$-.60(.31)^{0.050}$	$.087(.123)^{0.475}$	$.030(.11)^{0.782}$
lnFertiliz	β_2	$.075(.012)^{0.000}$	$.085(.04)^{0.033}$	-	$.0029(.001)^{0.015}$	-
lnOxen	β_3	$.48\ (.064)^{0.000}$	$.22(.054)^{0.000}$	$.70(.148)^{0.000}$	$.85(.083)^{0.000}$	$.96(.22)^{0.000}$
lnLabor	β_4	$.45(.090)^{0.000}$	$.38\ (.19)^{0.046}$	$.64(.155)^{0.000}$	$.19(.083)^{0.021}$	$.40(.20)^{0.047}$
RTS		1.31	0.686	0.74	1.13	1.39
Sigma v	σ_v	.084 (.011)	.125(.012)	0.170(.024)	.036(.011)	.064(.016)
Sigma u	σ_u	.122 (.023)	.156(.027)	.243(.052)	.231(.019)	.165(.027)
Sigma2	σ^2	.022 (.004)	.040(.007)	.088(.019)	.055(.009)	.031(.0076)
Lambda	λ	1.44 (.032)	1.25(.036)	1.43(.072)	6.44 (.026)	2.60(.040)
Gamma	γ	0.6746	0.6097	0.6716	0.9765	0.8711
LL		201.22	118.223	22.56	114.65	74.80
$\boldsymbol{Wald\ X^2}$		296.52	49.59	51.24	460.62	278.96
p-value		0.0000	0.0000	0.0000	0.0000	0.0000
Mean TE		.9111	.8883	.8335	.8570	.8823

Note: Figures in parentheses shows std. error of the parameter and the superscript numbers represent the p-value for the respective variable.

Source: Own survey data (2016)

Table 10 presents parameter estimates of stochastic frontier model for productivity of five crops (*teff*, wheat, bean, barley and sorgum) separately using conventional input variables. In addition to the parameter estimates of the coefficients of inputs, the table also contains the parameter estimate of the variance of the error components (the variance of the noise component and the variance of the inefficiency component) as well as the variance of the composite error. Moreover, there is also the log likelihood value of the final model and the chi-square test results of goodness of fit for the model for each crop. Lastly, in this table the mean technical efficiency of each crop is presented.

Table 11: Determinants of technical inefficiency score for the productivity of five crops

Variables	$\delta's$	*Teff*	Wheat	Bean	Barley	Sorgum
Constant	δ_0	$-1.45(0.90)^{0.107}$	$-3.34(1.1)^{0.002}$	$-3.52(1.9)^{0.065}$	$-7.30(1.4)^{0.000}$	$-6.7(1.9)^{0.000}$
Sex						
Male	δ_1	$.92\ (.54)^{0.087}$	$.53(.51)^{0.301}$	$.33(.71)^{0.805}$	$1.14(.67)^{0.089}$	$2.21(1.4)^{0.113}$
Age	δ_2	$-.018(.011)^{0.096}$	$.031(.014)^{0.032}$	$.006(.02)^{0.929}$	$.08(.018)^{0.000}$	$.042(.02)^{0.045}$
Education	δ_3	$-.24(.071)^{0.001}$	$-.059(.071)^{0.403}$	$-.18(.103)^{0.096}$	$-.17(.10)^{0.103}$	$-.52(\ .32)^{0.054}$
Health status						
Severe illness	δ_4	$1.16\ (.36)^{0.001}$	$.99(.44)^{0.025}$	$.009(.49)^{0.595}$	$.42(.36)^{0.249}$	$.64(.59)^{0.279}$
Land quality						
Medium	δ_5	$-1.35\ (.51)^{0.008}$	$-1.88(.59)^{0.002}$	$-.904(.53)^{0.086}$	$-.52(.56)^{0.359}$	$-2.9(1.2)^{0.016}$
Fertile	δ_5	$-1.82(.46)^{0.000}$	$-2.56(.63)^{0.000}$	$-1.85(.80)^{0.045}$	$-1.29(.7)^{0.059}$	$3.21(1.6)^{0.984}$
Extension	δ_6	$-.14\ (.068)^{0.045}$	$-.174(.10)^{0.086}$	$-.31(.14)^{0.015}$	$-.17(.09)^{0.056}$	$.14(.28)^{0.622}$
Credit						
User	δ_7	$-.191\ (.33)^{0.56}$	$-.66(.44)^{0.135}$	$-.593(.52)^{0.377}$	$-.94(.43)^{0.030}$	$2.2(1.45)^{0.078}$
ICT						
User	δ_8	$-.402\ (.30)^{0.179}$	$-.36(.38)^{0.340}$	$-.304(.47)^{0.535}$	$.075(.45)^{0.867}$	$.103(.52)^{0.842}$
Family size	δ_9	$-.136(.089)^{0.027}$	$-.107(.103)^{0.299}$	$-.008(.12)^{0.860}$	$.016(.11)^{0.876}$	$-.067(.2)^{0.723}$
Agro-chem.						
Used	δ_{10}	$.29(.36)^{0.422}$	$-.366(.378)^{0.333}$	$-0.94(.56)^{0.048}$	$.005(.47)^{0.992}$	
Imp. Seed						
Used	δ_{11}		$-.864(.46)^{0.061}$			

Note: Figures in parentheses shows std. error of the parameter and the superscript numbers represent the p-value for the respective variable.

Source: Own survey data (2016)

The Cobb-Douglas stochastic frontier model is specified for the analysis of input elasticity and technical efficiency of farmers for the production of five major crops per hectare in the study area. One stage approach, which includes conventional input variables for stochastic frontier model and variables that determine inefficiency simultaneously, was employed in the estimation of the model parameters by using MLE method. However, to make it readable the model results are presented with two tables separately, one for stochastic frontier model and the other for inefficiency effect.

The absence or the presence of technical inefficiency in the data can be tested using the generalized likelihood ratio test. First of all, whether the stochastic production function best fit the data or not was tested. This test was used to decide whether the stochastic frontier production function is more appropriate than the convectional production function. The null hypothesis for this test is H_0: σ_u=0 (there is no variation in productivity due to inefficiency or no inefficiency component) for specific crop productivity. In other words, the null hypothesis specifies that farmers in the study area are technically efficient in productivity and the variations in productivity are due to random variation. The test is based on the log likelihood ratio test by using the likelihood under the null (H_0: σ_u=0) and log likelihood for full model. The test results for each model are given in Table 12.

Table 12: log likelihood test for the existence of inefficiency component for each crop

Crop types	Null hypothesis	$\boldsymbol{X^2}$	P- value	Decision
Teff	H_0: σ_u=0	4.13	0.021	Reject H_0
Wheat	H_0: σ_u=0	5.49	0.010	Reject H_0
Bean	H_0: σ_u=0	3.46	0.031	Reject H_0
Barley	H_0: σ_u=0	55.46	0.000	Reject H_0
Sorgum	H_0: σ_u=0	6.85	0.004	Reject H_0

Source: Own survey data (2016)

The decision for the test in Table 12 indicates rejection of the null hypothesis in favor of the presence of inefficiency effects for each case. This shows, the variation of productivity is accounted by inefficiency effects in addition to the random variation. Therefore, the appropriate model for the productivity analysis for each crop is stochastic frontier model. This indicates, the variation in productivity not only accounted by the random disturbance term but also by another component called inefficiency term.

There is also another test on the inefficiency component that whether there exist one or more variables that could explain the variation in technical inefficiency. Log likelihood ratio was used to test the hypothesis: H_o: $\delta_1 = \delta_2 = \delta_3 = \cdots = \delta_9 = 0$.

This test is similar to testing $H_o: \gamma = 0$.

The LL ratio test can be computed as

LL ratio = -2[LLH_0 – LLH_1];

Where, LLH_0 is the LL value of restricted Cobb-Douglas stochastic frontier model (a model without explanatory variables of inefficiency effect model) and LLH_1 is the LL value of the unrestricted model (a model with all explanatory variables of inefficiency effect). This generalized likelihood-ratio test, LR, has asymptotic distribution, which is a mixture of X^2 distribution.

Table 13: Log likelihood ratio tests about the goodness of the inefficiency effect model

Crop types	Null hypothesis	LLR(λ)	Critical value	Decision
Teff	$\delta_1 = \delta_2 = \delta_3 = \cdots = \delta_{10} = 0$	83.88	14.69	Reject H_0
Wheat	$\delta_1 = \delta_2 = \delta_3 = \cdots = \delta_{11} = 0$	71.06	15.37	Reject H_0
Bean	$\delta_1 = \delta_2 = \delta_3 = \cdots = \delta_{10} = 0$	16.2	13.90	Reject H_0
Barley	$\delta_1 = \delta_2 = \delta_3 = \cdots = \delta_{10} = 0$	85.4	14.69	Reject H_0
Sorgum	$\delta_1 = \delta_2 = \delta_3 = \cdots = \delta_9 = 0$	29.46	13.20	Reject H_0

Source: Own survey data (2016)

The calculated value of LL ratio was compared to the critical values of mixture of X^2 distribution with the respective degrees of freedom to accept or reject the null hypothesis at 5% level of significance. Since all calculated LL ratio values are greater than the critical value at 5 % level of significance, the null hypotheses that the determinant variables in the inefficiency effect are simultaneously equal to zero are rejected. In other words, there exists technical inefficiency implying that there is at least one variable that explains the variation in technical inefficiency.

After checking the existence of inefficiency, the next task is the distributional assumption of the composite error. The normal-half normal distributional assumption of the composite error in stochastic frontier model considers the assumption of normal distribution for noise and half normal for inefficiency component. The density function of the composite error is the joint density as the product of normal and half normal density assuming independence of noise and inefficiency component. The density function of this composite error is skewed to the negative direction. This helps to test graphically the normal-half normal distributional assumption of the composite error. Based on this, the graphs (histogram with curve) of the residual (for composite error) in the stochastic frontier model for five crops separately skewed in the negative direction are shown graphically in Appendix 2 (Appendix Figures). This indicates the fulfillment of the distributional assumption of normal-half normal of the composite error.

For the overall goodness of fit about the stochastic frontier model, the log likelihood test result given in Table 14 indicates that the null hypothesis of all the parameters are equal to zero is rejected for each crop separately. This tells there is at least one parameter in the model different from zero. Moreover, the result for the individual parameter Wald test (based on p-value) indicates that the value of the parameter is different from zero for significant variables.

Table 14: Goodness of fit test for the stochastic frontier model for each crop

Crop type	Null hypotheses	**Wald X^2**	p-value	Decision
Teff	$H_0:\beta_1=\beta_2=\beta_3=\beta_4=0$	437.40	0.0000	Reject H_0
Wheat	$H_0:\beta_1=\beta_2=\beta_3=\beta_4=0$	145.77	0.0000	Reject H_0
Bean	$H_0:\beta_1=\beta_3=\beta_4=0$	64.65	0.0000	Reject H_0
Barley	$H_0:\beta_1=\beta_2=\beta_3=\beta_4=0$	390.84	0.0000	Reject H_0
Sorgum	$H_0:\beta_1=\beta_3=\beta_4=0$	345.96	0.0000	Reject H_0

Source: Own data (2016)

Additionally, the overall goodness of fit test for the simultaneous model results of the stochastic frontier and inefficiency effect model shows that the model fits the data adequately as the Wald X^2 test result shown above (Table 10). Multicollinearity test was done using Variance Inflation Factor (VIF) and contingency coefficients. Both tests of multicollinearity confirmed that there is no serious multicollinearity problem among explanatory variables (VIF<10 for continuous variables and contingency coefficient for categorical variables < 0.5). The results of the tests are given in Appendix 1 (Appendix Tables).

4.2.1.1. Input elasticity and returns-to- scale

The simultaneous parameter estimate results of the Cobb-Douglas stochastic frontier model and inefficiency effect by using MLE method for each crop independently were given in the above tables (Tables 10 and 11). For the stochastic frontier model, the explanatory variables considered are the conventional inputs used for the production of crops. In this case, seed, fertilizer, oxen and labor were used as input variables. *Teff* and wheat grower farmers used all the listed inputs. In case of barley growers, some of them did not use fertilizer and many of them use it. To include those farmers who did not apply fertilizer in the estimation of the frontier model, a very small value that approach zero was assigned for fertilizer non-users Wassie (2014). But fertilizer was omitted from bean and sorgum production due to the fact that farmers did not use it. Additionally, many inefficiency variables were also included in the inefficiency effect. Then the frontier and inefficiency effect parameters were estimated simultaneously by using maximum likelihood estimation method.

All the discussion and interpretations given below for five crops (*teff*, wheat, bean, barley and sorgum) productivity separately and independently are based on the results of the respective Cobb-Douglas stochastic frontier model given in Table 10. The stochastic frontier model for *teff* productivity shows that all inputs (seed, fertilizer, oxen-pair days and labor force) affect *teff* productivity positively and significantly at one percent level of significance. Timely and optimal level usage of these inputs improves *teff* productivity. This finding is supported by many findings (Otitoju and Arene, 2010; Akintayo, 2011; Bart *et al*., 2013; Wassie, 2014).

The parameter estimates of stochastic frontier model for *teff* productivity shows that a one percent increases in seed rate used increases the productivity of *teff* by 0.302 percent keeping other variables constant. A one percent increases in the quantity of fertilizer applied per hectare increases the productivity of *teff* by 0.075% keeping others constant. Similarly, a one percent increase on the number of oxen-pair days used per hectare increases *teff* productivity by 0.48%, keeping other variables constant. Moreover, a one percent increases in the number of labor force used per hectare increases the yield of *teff* by 0.45%, keeping other variables constant. This shows that up to optimal level increase of seed, oxen-pair days, fertilizer, and labor force increases *teff* productivity.

The summation of the partial elasticity of *teff* productivity accounted by every input for the production of *teff* was 1.31, which implies an increase in all inputs applied for *teff* production per hectare by one percent leads to a 1.31 percent increase on *teff* production per hectare. Therefore, an optimal increase in inputs applied for *teff* production per hectare results an increase on *teff* productivity.

The stochastic frontier model results of wheat productivity shows that fertilizer, oxen-pair days, and labor force have positive and significant effect on wheat productivity at 5%, 1% and 5% level of significance, respectively. This indicates optimal and timely usage of these inputs improves wheat productivity. This study supports studies done by many authors (Javed, 2009; Essa *et al*., 2011; Wassie, 2012; Jumo *et al*., 2014; Zahoor, 2014).

Based on the stochastic frontier model parameter estimates of wheat production per hectare, a one percent increase on the quantity of fertilizer used per hectare increased the productivity of wheat by 0.085% keeping other variables constant. In addition, a one percent increases in a number of oxen-pair days used per hectare increases productivity of wheat by 0.22% keeping other variables constant. Moreover, a one percent increase in labor force used per hectare leads to an increase in wheat productivity by 0.38% keeping other variables constant. The summation of the partial elasticity for wheat productivity with respect to every input was 0.69 showing a decreasing return-to-scale for wheat productivity. Therefore, an increase in all inputs used per hectare by one percent increases wheat productivity by less than one percent.

The Cobb-Douglas stochastic frontier model result for bean productivity shows that seed, oxen-pair days, and labor force had positive and significant effect on bean productivity at 5%, 1%, and 1% level of significance, respectively. This implies an optimal increase in these inputs would increase the productivity of bean. Seed has significant effect on bean productivity at 5% level of significance but the sign is negative implying it is over utilized.

The coefficients of the input variables in the stochastic frontier model of bean productivity shows that a one percent increase in the number of oxen-pair days used per hectare increases the productivity of bean by 0.70% keeping other variables constant. Similarly, a one percent increases in number of labor force used per hectare increases productivity of bean by 0.64% keeping other variables constant. The return to scale for bean productivity is 0.74, which is less than one, implying decreasing return to scale. A one percent increase on all inputs used per hectare results in a 0.74 percent increase in bean production per hectare with the given production technology.

The estimation result of stochastic frontier model for barley productivity indicates that fertilizer, oxen-pair days, and labor force used per hectare have positive and significant effect on barley productivity at 5%, 1%, and 5% level of significance, respectively. The coefficients of the stochastic frontier model for barley productivity indicate that a one percent increase in the quantity of fertilizer applied per hectare increases barley productivity by 0.0029% as other variables remain constant. Additionally, a one percent increase in the number of oxen-pair days used per hectare increases barley productivity by 0.85% and a one percent increase in the number of labor force used per hectare increases barley productivity by 0.19% keeping other variables constant. The return to scale for barley productivity was 1.13. This indicates a one percent increase in all inputs used per hectare for barley production increases barley productivity by 1.13 percent with the given production technology.

The results of stochastic frontier model for sorgum productivity show that oxen-pair days and labor force had positive and significant effect on the productivity of sorgum at 1% and 5% level of significance, respectively. This study supports the studies done by many researchers (Adam *et al.*, 2005; Chimai, 2009; Abba, 2012). The result indicates that a one percent increase in the number of oxen-pair days used per hectare increases sorgum productivity by 0.96% keeping other variables constant. In addition, a one percent increase on the number of labor force used per hectare increases sorgum productivity by 0.40% keeping other variables constant. The return to scale for sorgum productivity was 1.39 implying a one percent increase on all the inputs applied per hectare results more than one percent increase for sorgum productivity. This shows a one percent increase in the inputs used per hectare increases sorgum productivity by 1.39% within the given production technology.

The values of γ (the ratio of the variation due to inefficiency and over all variation) of the stochastic frontier model for *teff*, wheat, bean, barley, and sorgum production per hectare were 0.6746, 0.6097, 0.6716, 0.9765, and 0.8711, respectively (Table 10). The γ value of 0.6746 for *teff* production per hectare indicates that 67.46% of the variation in *teff* productivity is explained by technical inefficiency. Similarly, the variations in wheat, bean, barley, and sorgum productivity accounted by technical inefficiency are 60.97, 67.16, 97.65, and 87.11 percent, respectively. The high values of γ for bean and barley productivity indicate that the variability of productivity of bean and barley are due to technical inefficiency.

The existence of technical inefficiency has been shown above in Table 12 by using log likelihood ratio test. Due to this, the technical efficiency score for each observation was predicted based on the results of stochastic frontier model. Depending on this, the mean level of technical efficiency for *teff*, wheat, bean, barley, and sorgum productivity was found to be 91.11, 88.83, 83.35, 85.70 and 88.23 percent, respectively (Table 15).

Table 15: Summary of efficiency scores by crop type

Variable	Observation	Mean	Std. Dev.	Min	Max
Teff	204	0.9111	0.045	0.6776	0.9765
Wheat	187	0.8883	0.050	0.5619	0.9671
Bean	172	0.8335	0.076	0.4461	0.9438
Barley	115	0.8570	0.114	0.3798	0.9869
Sorgum	80	0.8823	0.073	0.6354	0.9775

Source: Own survey data (2016)

The summary statistics of technical efficiency scores for each crop production per hectare is given in Table 15. The mean technical efficiency score for bean productivity can be interpreted as, given the level of inputs and the current technology, there is a room to boost bean productivity by 16.65 percent. Similarly, given the level of inputs and the current technology there is a room to boost *teff*, wheat, barley, and sorgum productivity by 8.89, 11.17, 14.3 and, 11.77 percent, respectively.

4.2.1.2. Estimation of determinants of inefficiency

The determinants of technical efficiency and stochastic frontier model of *teff*, wheat, bean, barley, and sorgum productivity are simultaneously estimated by using maximum likelihood estimation method and presented in separate tables to make it readable. The results of the inefficiency effect for five crops are separately presented in Table 11. The estimated coefficients are based on inefficiency effect of the variables for crop productivity and the result also tells about the technical efficiency with only reversing the sign of the coefficients. This means the coefficient of the variable is negative for inefficiency implying the variable positively affects the technical efficiency of crop production per hectare. All the discussions and interpretations for determinants of inefficiency are based on the results given in Table 11.

The results in the determinants of inefficiency for *teff* productivity shows that the variables significantly affecting inefficiency are sex of household head, age of household head, education level of the household head, health status (severe illness category with the reference category not severe illness), land quality (medium and fertile category with reference to infertile category), number of extension contact, and family size. This study result supports the study done by many researchers (Minten *et al*., 2013; Elias *et al*., 2014 and Wassie, 2014). Except age and health status, all significant variables have positive effect on technical efficiency of *teff* productivity.

The coefficients for education and extension are negative for inefficiency of *teff* productivity indicating that technical efficiency increases with increase in years of education of the household head and number of extension contact, respectively. Keeping other variables constant, for a unit increase in number of extension contact increases the technical efficiency of *teff* productivity by a score of 0.137 at 5% significant level. Other variables keep constant, for a one year increase in education level of the household head increases the technical efficiency by a score of 0.24 at 1 percent significance level. This might the case that farmers with more years of education and more number of contact with extension agent tend to be more technically efficient on *teff* productivity, presumably, due to their enhanced ability to acquire technical knowledge, guidance for practical best way of farming, which makes them closer to the frontier yield. In addition, the coefficient for land quality for medium and fertile category are negative indicating that technical efficiency increases with medium and fertile land with respect to infertile land (reference). Keeping other variables constant, for a household having medium and fertile land increases the technical efficiency of *teff* productivity by a score of 1.35 and 1.82, respectively at 1 percent significant level. This implies that keeping and maintaining soil fertility by different soil conservation method helps to improve efficiency of *teff* production per hectare. Health problem in the household affect technical efficiency negatively. The coefficient of health status in the category severe illness shows negative effects on technical efficiency when compared as not severe illness (reference) for the productivity of *teff*. Other variables keep constant, for a household faced severe illness increases the technical inefficiency by a score of 1.16 at 10 percent significant level.

The results of determinants of inefficiency for wheat productivity shows that the variables that significantly affect inefficiency are age of the household head, health status of the household, land quality, improved seed and number of extension contact. Among the significant variables age and health status have positive effect on inefficiency and the remaining significant variables have negative effect on inefficiency for wheat productivity. The sign of the coefficients of the variables are similar to the priori expectation. This study supports studies done by many researchers (Javed, 2009, Essa *et al*., 2012; Wassie, 2012).

The coefficient for age is positive for inefficiency indicating that age affects technical efficiency negatively. Keeping other variables constant, for a one year increase for the age of the household head decreases the technical efficiency of wheat productivity by a score of 0.031 at 5% significant level. This means as age of the household head increases, technical efficiency of wheat productivity decreases implying older farmers are less technically efficient than younger ones. This might be due to the factor that older farmers are more conservative to adopt new technologies and are likely to remain with traditional way of production that might lead to higher level of inefficiency. Similarly, health problem in the household affects inefficiency positively. The coefficient is positive indicating the occurrence of severe illness problem in the household affects technical efficiency negatively as compared to not severe illness (reference). Other variables keep constant, for a household faced severe illness problem increases the technical inefficiency by a score of 0.99 at 5 percent significant level compared to the households not faced the problem. This implies the households who faced the problem are less technically efficient as compared to the households that did not face the problem for the productivity of wheat.

The other significant variable is land quality in the medium and fertile category with the reference in the infertile category. Keeping other variables constant, for a household having medium and fertile land increases the technical efficiency of wheat productivity by a score of 1.88 and 2.56, respectively at 1 percent significant level compared as the household who cultivate infertile land (reference category). This implies households who cultivate fertile land for wheat productivity are better in technical efficiency than those who cultivate infertile land. Therefore, to improve technical efficiency of wheat productivity, improving and maintaining soil fertility by using different mechanisms of soil conservation is the best option at hand to improve wheat productivity. Moreover, the coefficient of extension shows that the number of extension contact affects technical efficiency positively. This implies keeping other variables constant, for a one unit increase in number of extension contact increases the technical efficiency of wheat productivity by a score of 0.174 at 10 percent significant level. Additionally, using improved wheat seed affects technical efficiency positively. Keeping other variables constant, a household used improved seed increases the technical efficiency of wheat productivity by a score of 0.864 at 10 percent significant level. This means households who used improved seed are better in technical efficiency as compared to non-user.

The results on the inefficiency effect for bean productivity shows that education level of the household head, number of extension contact, land quality (medium and fertile with reference to infertile) and agrochemical (user with reference to non-user) have positive and significant effect on technical efficiency. This study finding is supported by the findings of Essa *et al*. (2012). The sign of the coefficients of the significant variables are similar to priori expectation. Keeping other variables constant, a one year increase in education level of the household head increases the technical efficiency of bean productivity by a score of 0.18 at 10 percent level of significance. Similarly, keeping other variables constant, for a unit increase in number of extension contact increases the technical efficiency of bean productivity by a score of 0.31 at 5% significant level. This shows that educating farmers help the farmer to improve technical efficiency of bean production per hectare. Land quality (medium and fertile category) is better in TE as compared to reference category (infertile). Keeping other variables constant, a household used agro-chemical increases the technical efficiency of bean productivity by a score of 0.94 at 10 percent significant level. Agro-chemical users are better in TE as compared to non-user.

The results of determinants of inefficiency for barley productivity shows that age of the household head, education level of the household head, land quality, number of extension contact and credit significantly determine the level of technical efficiency. Among the significant variables, education level of the household head, land quality, number of extension contact and credit affect TE positively. Age of the household head affects technical efficiency negatively. The sign of the coefficients of the variables are similar to the priori expectation.

The coefficient of age in the inefficiency effect of barley productivity indicates that a one year increase for age of the household head decreases technical efficiency by a score of 0.08 at 1 percent level of significance. The coefficient of land quality indicates that technical efficiency affected positively when the land is fertile compared with the reference infertile. This indicates keeping other variables constant, for a household having fertile land increases the technical efficiency of barley productivity by a score of 1.29 at 10 percent significant level. Additionally, using credit also improves technical efficiency of barley productivity compared to non-user (reference). Other variables keep constant, for a household having access to credit increases the technical efficiency of barley productivity by a score of 0.94 at 5 percent significance level. Similarly, the coefficient of extension is negative in the inefficiency effect shows that number of extension contact affects technical efficiency positively. This implies keeping other variables constant, for a one unit increase in number of extension contact increases the technical efficiency of barley productivity by a score of 0.17 at 5 percent significance level.

The results of the determinants of inefficiency for sorgum productivity shows that age of the household head, land quality, credit and education level of household head have significant effect on technical efficiency of farmers for sorgum productivity. This finding supported the findings of Adam *et al*. (2005), Bernadette (2009), Chimai (2009) and Abba (2012) . Among the significant variables on technical efficiency of sorgum productivity land quality and education affects technical efficiency positively and the remaining significant variables have negative effect on technical efficiency. Keeping other variables constant, a one year increase for age of the household head decreases technical efficiency by a score of 0.042 at 5 percent level of significance. A household having medium fertility of land increases the technical efficiency of sorgum productivity by a score of 2.88 at 5 percent significant level reference to infertile land. Keeping other variables constant, a one year increase in education level of the household head increases the technical efficiency of sorgum productivity by a score of 0.52 at 5 percent level of significance. This shows an increase in the level of education leads to an increase in technical efficiency of farmers for sorgum productivity. Generally, as the determinants of inefficiency for most crops productivity shows that education level of the household head, number of extension contact, credit and land quality have positive and significant effect on technical efficiency of crop productivity.

4.2.2. Logistic regression model for poverty analysis

4.2.2.1. Estimation of model parameters

Table 16 present the results of the logistic regression model of the poverty status of the household. The logistic regression model was fitted using eleven explanatory variables for the dependent variable poverty status of the household based on annual income. The parameters in logistic regression were estimated by using maximum likelihood estimation method. In this model, sex of the household head, marital status of the household head, crop productivity (ln transformed), natural risk, place of residence, dependency ratio, irrigation, non-labor income, non or off-farm activity, distance to the main market, and livestock holding in tropical livestock unit were used as independent variables. The dependent variable, the poverty status of the household, was measured on a dichotomous scale (i.e. non-poor and poor) based on their annual income. The table contains the estimated coefficients **($\hat{\beta}$),** the standard error of the estimates (S.E ($\hat{\beta}$)) which helps in computing the values of the Wald statistics.

Table 16: Estimation results of the logistic regression model for poverty analysis

Variables	$\hat{\beta}$	S.E($\hat{\beta}$)	Wald	p-value	Exp($\hat{\beta}$)
Constant	37.066***	12.830	8.352	0.004	1.25e+16
Sex of household head					
Male	-1.694*	.832	4.162	0.042	.184
Marital status					
Married	1.918	1.302	2.161	0.141	6.806
Divorced	.539	1.461	0.137	0.712	1.714
Widowed	-.232	1.541	0.023	0.880	.793
lnagri productivity	-3.892***	1.420	7.508	0.006	.0204
Place of residence					
Midland	2.392***	.679	12.390	0.000	10.932
Dependency ratio	1.453***	.558	6.760	0.009	4.276
TLU	-.449***	.100	20.160	0.000	.638
Non-Labor income					
Yes	-2.500***	.556	20.250	0.000	.082
Natural risk					
Yes	.758	.516	2.161	0.141	2.135
Irrigation					
User	-2.213***	.663	11.156	0.001	.109
Off-farm activity					
Participate	-1.184**	.488	5.856	0.015	.306
Distance to main market	-.017	.046	0.144	0.707	.983

Note: *, **, and *** shows significant at 10%, 5%, and 1% level of significance, respectively.

Source: Own computation (2016)

Among the explanatory variables, sex of the household head, crop productivity expressed in market value, place of residence, dependency ratio, livestock holding in TLU, non-labor income, irrigation, and non or off-farm activity affects poverty status of the household significantly. Sex of household head and off-farm activity are significant at 5% level of significance, the remaining are significant at 1% level of significance. Except place of residence and dependency ratio all have negative effect on poverty implying they have a role for poverty reduction.

4.2.2.2. Assessing the goodness of fit for the model

The likelihood ratio test of a model tests the difference between -2LL for the full model and -2LL for the initial chi-square in the null model. This is called the model chi-square test. The null hypothesis that all the regression coefficients except the constant are zero specified as:

H_0: β_1=β_2 =, … , = $\beta_k = 0$ versus H_1: $\beta_j \neq 0$ for at least one j where, j=1, 2 . . . k

The above hypothesis can be tested by using log likelihood ratio (LR) test. The value of the LR (Chi-square) is 129.48 with p-value 0.0000 shown in Appendix 1(Table 9). This leads rejection of the null hypothesis at one percent level of significance showing that there is at least one significant variable in the model that determines the poverty status of the household. In other words, the model as a whole fits significantly better than an empty model. This brings out the implication that there exist a significant relationship between the poverty status of the household and at least one of the study independent variables.

For individual coefficient test by using Wald test for the hypothesis H_0:$\beta_j = 0$ vs H_1:$\beta_j \neq 0$,$j = 1,2, \ldots, k$ leads rejection of the null hypothesis for each test due to the high value of Wald statistic for significant variables. This indicates statistical significance of each coefficient (β_j) in the model.

The Hosmer-Lemeshow (HL) test used to test the goodness of the model to fit the data. In this case, the hypothesis to be tested is: H_0: Model fits the data versus H_1: Model does not fit the data. For this test, the HL test statistic is 11.94 (p-value=0.1539) based on chi-square distribution with 8 degree of freedom shown in Appendix 1(Table 10). This shows that there is no sufficient evidence to reject the null hypothesis and it confirms that the model fits the data adequately. Generally, based on the results of the model chi-square goodness fit test, the Wald test (for individual coefficients) and the Hosmer-Lemeshow test the fitted model is statistically satisfactory. In addition to this, there is no multicollinearity problem among categorical variables as contingency coefficient is less than 0.5 shown in Appendix 1 (Table 8).

In addition to global examination of a model, it is also useful to examine the characteristics of individual cases in the data set. Analog of Cook's influence statistics is one way of analyzing influence statistic in logistic regression. In logistic regression, a case is identified as influential if its Cook's distance is greater than one. Since Cook's influence for each one of the observations in our data is less than one (minimum zero and maximum 0.586 which was less than one with mean 0.038) indicates that there are no influential observations shown in Appendix 1(Table 11).

4.2.2.3. Interpretation of the coefficients of logistic regression model

The logistic regression model result indicates that poverty status of the household is affected by many factors considered in the study. The interpretation in this part is based on the results given in Table 16. The estimation results of logistic regression model shows that the explanatory variables that significantly determine the poverty status of the households are sex of the household head, crop productivity expressed in market value, place of residence, dependency ratio, irrigation, non-labor income, non or off-farm activity and livestock holding in TLU. This study finding is supported the findings of many studies (Ayalneh *et al.*,2005; Geda *et al*., 2005; Alem, 2007; Amjad and Maqbool, 2008; Apata *et al*., 2010; Ayalneh, 2011; Adem, 2013 and Ayele *et al*., 2013). Among the significant explanatory variables place of residence and dependency ratio have positive coefficients. The remaining significant explanatory variables (sex of the household head, crop productivity, irrigation, non-labor income, non or off-farm activity and livestock holding in TLU) affect poverty negatively implying that they play a role in poverty reduction.

Interpretation of the coefficients of the fitted logistic regression model is based on the log odds or odds ratio. Among the significant variables, sex of the household head affects poverty negatively. This result confirmed with the results obtained by Ayalneh *et al*. (2005) and Apata *et al*. (2010). Thus, the odds of being poor for male headed households is 0.184 times less than for female headed households (reference category), holding the other predictors constant. Moreover, crop productivity has significant and negative effect on poverty. This result was similar to the study results of Germano *et al*. (2005), Alem (2007) and Amjad and Maqbool (2008). The odds of poor household relative to non-poor household is decreased by 0.0204 times for a unit increase of the ln transformed of crop productivity, keeping other variables in the model constant. This indicates that an increase in crop productivity leads to a reduction of the household being poor.

In the case of place of residence, the odds of being poor for the households who live in the midland is 10.93 times higher than for the household who live in lowland (reference category). The coefficient of dependency ratio in the model is positive indicates that a change in dependency ratio leads positive change in the odds that the household being poor. This shows dependency ratio affects poverty positively supported the study done by Amjad and Maqbool (2008). In other words, the odds of poor household relative to non-poor household is increased by 4.276 times for a unit increase of dependency ratio in the household, keeping other variables in the model constant.

Another significant variable that has negative coefficient is livestock holding in TLU implying that affect poverty negatively. This finding was similar to the findings of Amjad and Maqbool (2008), Apata *et al.* (2010), Ayalneh (2011) and Adem (2013). The odds of poor household relative to non-poor household is decreased by 0.638 times for a unit increase of livestock holding in TLU for the household, keeping other variables in the model constant. In the case of non-labor income, the odds of being poor for the household who got non-labor income is 0.082 times less than for the households who could not get non-labor income (reference category), holding the other variables constant.

Irrigation (user class) also affects poverty negatively. This finding is confirmed with the finding of Ayalneh *et al* (2011) and Adem (2013). Thus, the odds of the household being poor for irrigation user is 0.109 times less than for irrigation non-user households (reference category), keeping other variables constant. This implying that the households who use irrigation are less likely to be poor compare to irrigation non-user. For this reason, dispread irrigation in the district plays a role in poverty reduction.

Finally, participation of the household in non or off-farm activities affects poverty negatively as the coefficient showed. This result confirmed that the results of the study obtained by Amjad and Maqbool (2008) and Ayalneh (2011). Thus, the odds of being poor for the households who participate in non or off-farm activities is 0.306 times lower than for the households who were not participate in non or off-farm activities (reference category), holding the other variables constant. This implies participating in non or off-farm activities play its own role for poverty reduction. Generally, the coefficients that have negative sign among the significant variables play a role in poverty reduction. The logistic regression model fitted in this study also helps to estimate or predict the probability ($\hat{\pi}$) of the dependent variable for any given independent variable.

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

This section has two sub sections. The first subsection deals with summery and conclusion of the major findings. The second subsection deals with recommendations forwarded based on the study results.

5.1. Summary and Conclusion

The study was intended to assess productivity and technical efficiency of the production of five major crops (*teff*, wheat, bean, barley and sorgum) and poverty status of the household in Menz Keya Gebriel district of North Shewa zone, Ethiopia. Specifically, to estimate the level of responsiveness (elasticity) of yield with respect to factor inputs, evaluate the return to scale for the production function, to determine the level of technical efficiency and factors affecting it, to analyze factors associated with poverty status of household and the effect of productivity on poverty in the district. The data for the study were collected from 207 randomly selected sample households from Menz Keya Gebriel district in July and August, 2015 using stratified random sampling based on agro ecology. The productivity of crop was measured as partial factor productivity specifically land productivity (output of crop in kg per hectare) for each crop separately. The poverty status of the household was measured using the household annual income using a fixed poverty line set by World Bank. Both descriptive and econometrics methods were employed in this study. The descriptive statistic result shows that the average productivity of *teff*, wheat, bean, barley, and sorgum were 982.3, 1239.9, 979.60, 1044.8, and 953.1 kg/ha, respectively. Stochastic frontier model was used for productivity analysis. Logistic regression model was used to estimate the regression coefficients of explanatory variables which were assumed to influence the poverty status of the households.

The stochastic frontier model is used based on the hypothesis test on existence of inefficiency component in the error term. The log likelihood ratio test result shows the existence of inefficiency implies stochastic frontier production function is more appropriate than convectional production function or there is significant technical inefficiency variation among plots. Therefore, the analysis used Cobb-Douglas stochastic frontier models and inefficiency effect simultaneously to determine basic input elasticity and determinants of inefficiency respectively for each crop production per hectare separately. For this purpose, the study used basic input and determinants of inefficiency as an explanatory variable with the dependent variable productivity of the respective crop. Various variables that are expected to determine efficiency of farmers are estimated simultaneously with the stochastic frontier model (one stage estimation procedure) by maximum likelihood estimation (MLE) method.

Results of stochastic frontier model indicates that among conventional input variables seed, fertilizer, oxen-pair days and labor force affect positively and significantly for *teff* productivity, meaning that an increase in one of them will enhance productivity of *teff* keeping others effect constant. The stochastic frontier model result shows that fertilizer, oxen-pair days and labor force have positive and significant effect on wheat productivity. In the case of bean productivity oxen-pair days and labor force affect bean productivity positively and significantly. Seed also affect bean productivity significantly but its coefficient is negative indicates it is over utilized. The inputs fertilizer, oxen-pair days and labor force positively and significantly affect barley productivity. For sorgum productivity, oxen-pair days and labor force have positive and significant effect on productivity. The return to scale for *teff*, wheat, bean, barley and sorgum production per hectare was 1.31, 0.686, 0.74, 1.18 and 1.39, respectively. Generally, fertilizer, oxen-pair days and labor force affect *teff*, wheat and barley productivity positively and significantly. The positive coefficient of these variables indicates that optimal increase of these inputs increase the productivity of the crops.

The mean level of technical efficiency of *teff*, wheat, bean, barley, and sorgum productivity were 0.911, 0.888, 0.834, 0.857, and 0.882, respectively. The mean technical efficiency value of 83.4 percent for bean productivity indicates that there is a potential to boost bean productivity. In other words, this indicates that there is 16.6% scope for increasing bean productivity by using the present input and technology. Generally, an important conclusion drawn from this is that, there exists a considerable room to increase the level of technical efficiency and improve *teff*, wheat, bean, barley, and sorgum productivity.

Age of the household head, education level of the household head, land quality, number of extension contact, and family size affect technical efficiency positively and significantly for *teff* productivity. Health problem in the household affect technical efficiency negatively for *teff* productivity. Maintaining and improving soil fertility, contacting extension agent and getting technical help improves *teff* productivity. The TE in wheat productivity is mainly explained by age of the household head, health status, land quality, number of extension contact and improved seed. Among these significant variables, age and health status affect TE negatively and the rest affect TE positively.

The technical efficiency on bean productivity is explained by education of the household head, land quality, number of extension contact and agro-chemical. All these significant variables affect TE positively. Therefore, improving land fertility by using different soil conservation methods, using agro-chemical, increasing the number of extension contact increases bean productivity. Age, education, land quality, extension contact and credit are the major determinates of inefficiency for barley crop productivity. Except age, all affect inefficiency negatively for barley productivity. Therefore, improving land fertility, using credit and increase number of extension contact used to enhance barley productivity by improving TE. For sorgum productivity, the inefficiency mainly explained by age of the household head, years of education of the household head, land quality and credit. Generally, the results of the inefficiency effect for most crops shows that education level of the household head, land quality, number of extension contact, using credit, using agro-chemical helps to improve the technical efficiency of crop productivity. Therefore, proper usage of those determinants helps the farmer to boost productivity of *teff*, wheat, bean barley and sorgum.

In addition to stochastic frontier model, the study used logistic regression model for the analysis of poverty status of the household. The dependent variable in this case is poverty status of the household (non-poor, poor) and using 11 explanatory variables. The logistic regression model was fitted by using maximum likelihood estimation method. Among the explanatory variables 7 are significantly determine the poverty status of the household. The explanatory variables that significantly determine the poverty status of the households were crop productivity as market value (crop price in birr/ha), place of residence, dependency ratio, live stock holding in TLU, non or off-farm activity, non-labor income and irrigation. Among these significant variables, except place of residence and dependency ratio, all plays significance role in poverty reduction. Improving crop productivity, using irrigation and participating in non or off farm activities found to be reduced poverty. Therefore, improving farmers' crop productivity, expanding irrigation, enhancing non or off-farm activities and diversifying income generating sources of the farm households are an important intervention to fight with and get out of poverty in the study area.

5.2. Recommendations

For the improvement of crop productivity, technical efficiency and the reduction of poverty in the study area, in line with the finding of this study the following recommendations are forwarded.

1. Government investment in agriculture continued in advance through agricultural input subsides for fertilizer, improved seed and extension service to improve crop productivity and technical efficiency in the district.
2. Fertilizer affects crop productivity positively and significantly. Therefore, the concerned body supplies fertilizer with enough amounts timely at a reasonable price, increasing the level use of fertilizer by the farmers through different policy initiatives and continuous training as well as follow up on the application of fertilizer for improving crop productivity in the district.
3. Improving oxen holding of farmers by introducing initiatives such as targeted credit, improved animal health service and technologies that enhance the traction power of the existing oxen. This leads improve crop productivity in the study area.
4. Better utilization of farm labor should be put in place. Policies that motivate and mobilize the proper usage of labor force in agricultural activities should be given great attention.
5. The inputs, fertilizer, oxen-pair days and labor force affect crop productivity positively. Therefore, the concerned body due attention on continuous training and field follow up of farmers for recommended rate of input uses during pre-harvesting agricultural activities in the study area.
6. The study result shows positive effect of credit and extension service on technical efficiency of crop productivity, it is therefore of great importance that the agricultural development strategy focuses on creating an environment that facilitates farmers'

accessibility better extension provision and improved access to credit by establishing more formal credit institution in the study area.

7. In addition to strengthening the existing extension service provided to farmers, to improve technical efficiency of crop productivity, efforts should be made to train or teach farmers by adult education and training programs targeted for farm households to develop their level of understanding and publicize ICT used to get information about agriculture and related issue.
8. Improve and maintain land fertility by applying appropriate soil fertility management practice to improve technical efficiency of crop productivity.
9. The study result shows that livestock holding affects poverty negatively. Therefore, stakeholders, in the study area should give much emphasis to improve the production and productivity of the sector through disseminating improved breeds, providing health service nearby and improving feeding practice. The concerned body takes all appropriate measures for improving livestock holding to reduce poverty.
10. As the study shows, using irrigation significantly reduce poverty. Therefore, enhancing the started expansion of irrigation for a large scale in the area must be continued so as to reduce poverty.
11. The study result indicated that crop productivity affects poverty negatively. Therefore, the already designed policy that improve farm production and productivity must be encouraged thereby may reduce poverty. It is advisable that improving farmers' crop productivity give much emphasis by the concerned body to reduce poverty in the study area.
12. Participating in non or off farm activities found to be reduced poverty. Therefore, it is advisable that improving the smallholder farmers' crop productivity is not the only means to reduce poverty but also through enhancing non or off-farm activities. Diversifying income generating sources of the farm households is an important intervention to fight with and get out of poverty in the study area. Awareness creation activity regarding the role of income generation other than agricultural production has to be undertaken.

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7. APPENDICES

Appendix 1: Appendix Tables

Table 1: Conversion factors to compute tropical livestock unit (TLU)

Livestock type	Conversion factor (TLU)
Ox/Cow	1.00
Calf	0.25
Heifer	0.75
Mule	0.70
Donkey	0.50
Horse	0.80
Sheep, goat	0.10
Poultry (chicken)	0.01

Source: FAO (2004)

Table 2: Variance Inflation Factor (VIF) for input and inefficiency variables.

Input	Teff		Wheat		Bean		Barley		Sorgum	
variables	VLF	1/VIF	VLF	1/VIF	VLF	1/VIF	VLF	1/VIF	VLF	1/VIF
lnLabor	4.57	0.219	2.81	0.356	1.41	0.709	3.64	0.2746	6.26	0.159
lnoxendays	4.30	0.232	1.26	0.792	2.72	0.368	5.54	0.180	6.12	0.164
lnfertilizer	2.06	0.486	2.03	0.493	-	-	1.63	0.6148	-	-
lnlandsize	1.55	0.646	1.04	0.965	1.16	0.865	1.15	0.868	1.06	0.9414
lnseed	1.40	0.712	2.06	0.487	2.80	0.357	3.95	0.253	2.11	0.4737
Mean VIF	2.78		1.84		2.02		3.18		3.89	
Inefficiency variables										
extension	1.25	0.799	1.65	0.607	1.10	0.913	1.91	0.523	5.16	0.193
education	1.23	0.812	1.65	0.607	1.09	0.917	1.86	0.539	5.56	0.1798
Family size	1.02	0.981	1.09	0.919	1.03	0.968	1.02	0.985	1.18	0.8458
age	1.00	0.999	1.01	0.992	1.03	0.971	1.04	0.966	1.02	0.9823
Mean VIF	1.13		1.35		1.06		1.45		3.23	

Source: Own computation (2015)

Table 3: Contingency coefficient of variables in inefficiency effect for *teff* productivity

Variables	Sex HH	Health status	Land quality	Credit	ICT	Agro-chemical
Sex HH	1.0000					
Health status	-0.1377	1.0000				
Land quality	-0.0422	0.0136	1.0000			
Credit	-0.1817	-0.0782	0.4951	1.0000		
ICT	0.0462	-0.0486	0.1035	0.0920	1.0000	
Agro-chemical	0.0809	-0.1025	0.3889	0.2140	0.0419	1.0000

Source: Own computation (2015)

Table 4: Contingency coefficient of variables in inefficiency effect for wheat productivity

Variables	Sex HH	Health status	Land quality	credit	ICT	Agro-chemical	Improved seed
Sex HH	1.0000						
Health status	-0.0405	1.0000					
Land quality	0.0683	-0.1821	1.0000				
Credit	0.0367	-0.2260	0.3990	1.0000			
ICT	-0.0038	-0.0459	0.3114	0.1658	1.0000		
Agro-chemical	0.1592	-0.0670	-0.1123	-0.1164	-0.1155	1.0000	
Improved seed	-0.0496	-0.1144	0.3163	0.2869	0.2445	-0.0421	1.0000

Source: Own computation (2015)

Table 5: Contingency coefficient of variables in inefficiency effect for bean productivity

Variables	Sex HH	Health status	Land quality	credit	ICT
Sex HH	1.0000				
Health status	-0.2191	1.0000			
Land quality	-0.0905	0.0156	1.0000		
Credit	-0.0187	0.0473	0.1905	1.0000	
ICT	0.0040	-0.0516	0.0709	0.0316	1.0000

Source: Own computation (2015)

Table 6: Contingency coefficient of variables in inefficiency model for barley productivity

Variables	Sex HH	health status	land quality	credit	ICT	Agro-chemical
Sex HH	1.0000					
Health status	0.0523	1.0000				
Land quality	0.0587	0.0049	1.0000			
Credit	-0.0303	-0.0120	0.3104	1.0000		
ICT	0.1410	0.0722	0.0624	-0.0459	1.0000	
Agro-chemical	0.1433	0.0530	-0.2202	-0.1853	0.0750	1.0000

Source: Own computation (2015)

Table 7: Contingency coefficient of variables in inefficiency effect for sorgum productivity

Variables	Sex HH	health status	land quality	credit	ICT
Sex HH	1.0000				
Health status	-0.0104	1.0000			
Land quality	-0.1665	0.0926	1.0000		
Credit	-0.0851	0.0435	0.1347	1.0000	
ICT	0.1042	-0.1863	0.1690	0.1524	1.0000

Source: Own computation (2015)

Table 8: Contingency coefficient of variables in logistic regression model of poverty analysis

Variables	Sex	Placeresid	NonLaborinc	naturarisk	irrigation	Off-farm act
Sex	1.0000					
Place resid.	-0.0227	1.0000				
Non-Laborinc	0.0002	0.0607	1.0000			
Natural risk	0.0249	-0.1564	0.0631	1.0000		
Irrigation	0.0521	-0.1148	-0.0987	-0.4061	1.0000	
Off-farm act.	0.0025	0.0374	0.1566	-0.0612	0.2188	1.0000

Table 9: Goodness of fit test of the logistic regression model

Model	-2 Log Likelihood(-2LL)	Log Likelihood Ratio Test	
		Chi-Square	p-value
Intercept only	264.88	129.48	.000
Final	135.402		

Table 10: Hosmer-Lemeshow, goodness-of-fit test

goodness-of-fit test	Number of observations	Number of groups	HL test statistic (chi2(8))	p-value (Prob > chi2)
Hosmer-Lemeshow	207	10	11.94	0.1539

Table 11: Analog of Cook's influence statistics

Statistic	n	Min	Max	Mean	Std. deviation
Cook's influence	207	.00000	.58638	.0381277	.07572572

Appendix 2: Appendix Figures

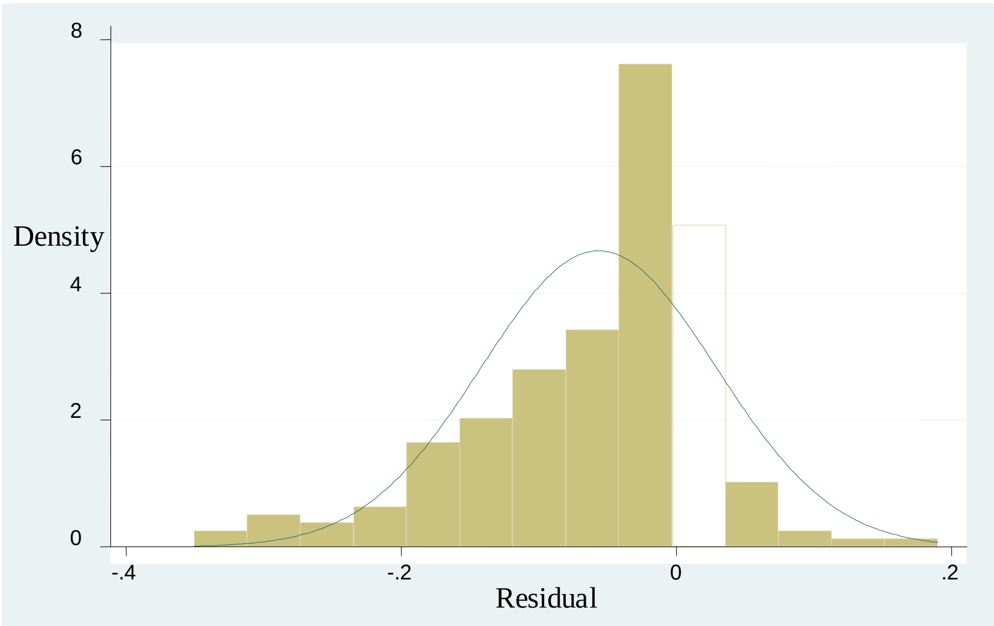

Figure 1: Histogram of the residual of SFM for teff productivity

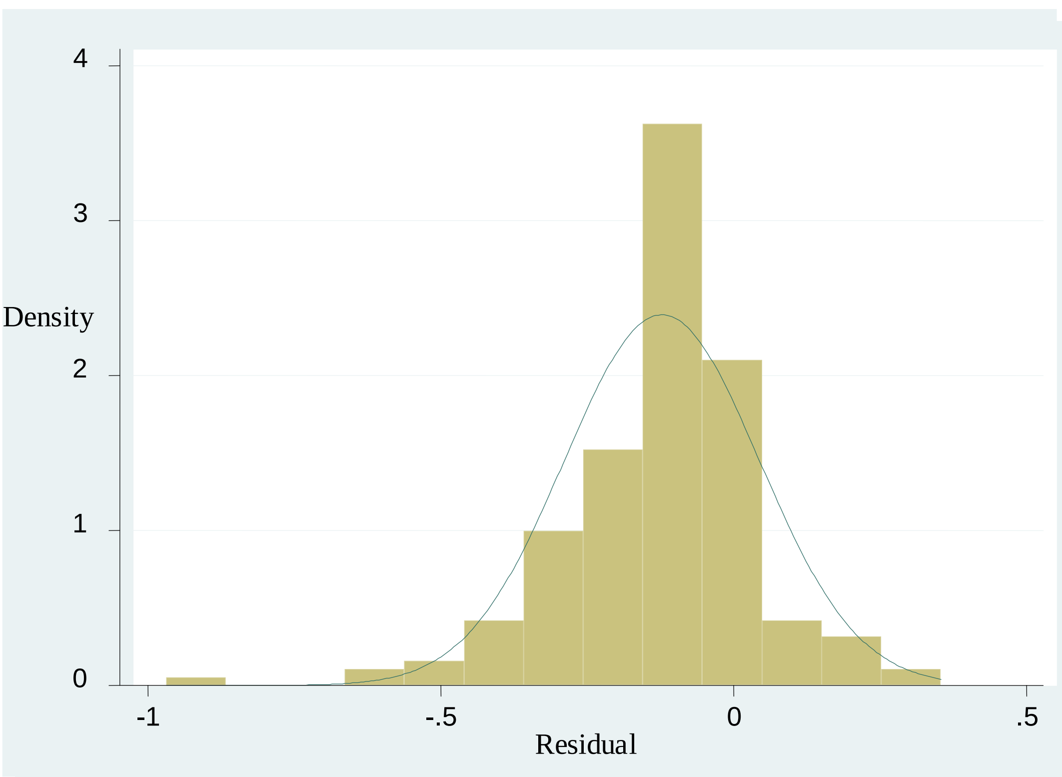

Figure 2: Histogram of the residual of SFM for wheat productivity

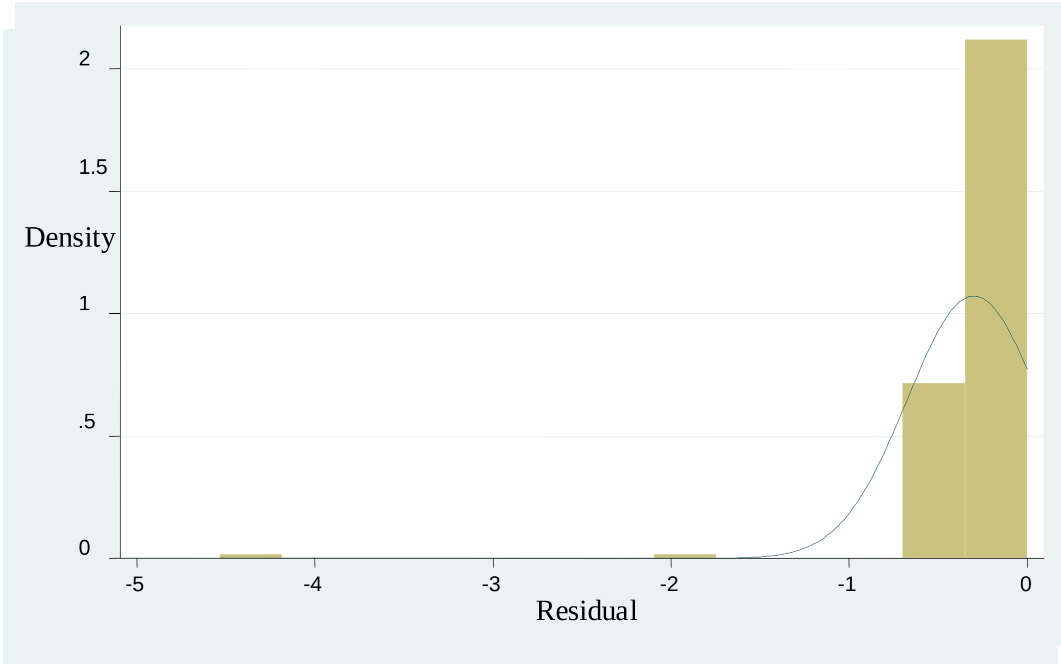

Figure 3: Histogram of the residual of SFM for bean productivity

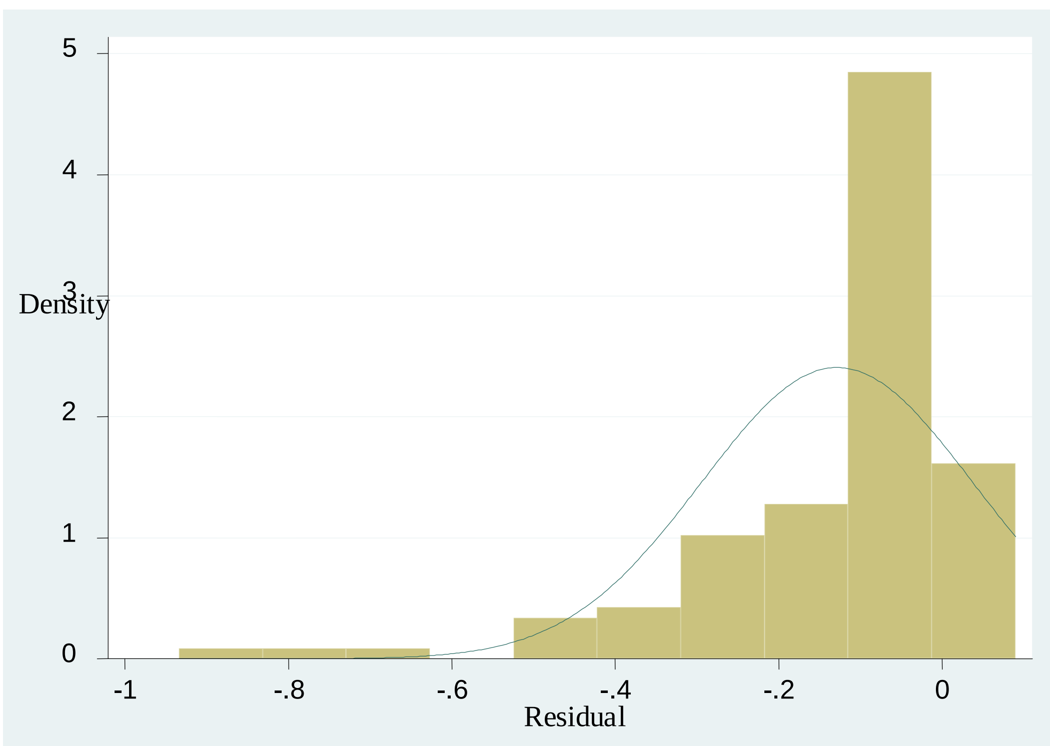

Figure 4: Histogram of the residual of SFM for barley productivity

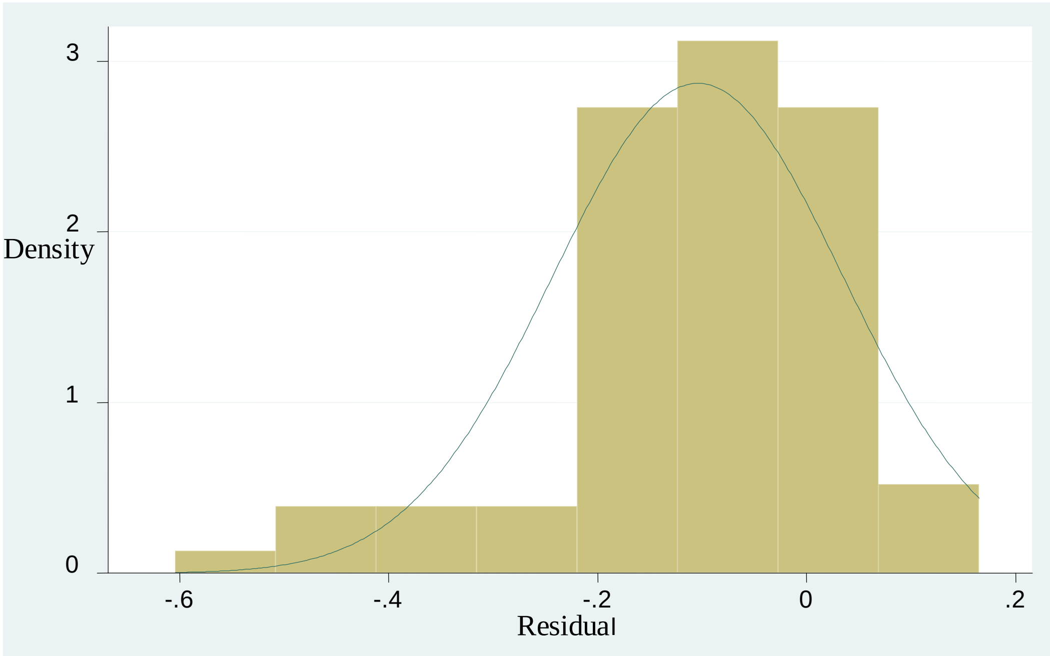

Figure 5: Histogram of the residual of SFM for sorgum productivity

Appendix 3: Survey Questionnaire

HARAMAYA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Survey Questionnaire

The questionnaire is prepared to undertake a study on crop productivity and its impact on poverty status of the rural household in Menz Keya Gebreal Woreda**.** The purpose of the questionnaire is to gather information on factors that affect crop productivity and the factors that determine the poverty status of the household. Dear respondents, the result of this study will help different stakeholders and policy makers to make appropriate measures for the improvement of agricultural productivity. Your responses are confidential. Therefore, you are kindly requested to provide genuine responses. Thank you for your time and cooperation!

Identification

Code ________________________ Date___________________

Interviewer name ____

Household head name (Optional)____

Kebele _______________________________Village (Gott) _______________________

Part I. Household characteristics and social issues

1.1. Place of residence of the household i) Kola [0] ii) Dega [1]

1.2. Sex of the household head i) Male [0] ii) Female [1]

1.3. Age of the household head ____

1.4. Current marital status of household head i) Single [0] ii) Married [1] iii) Divorced[2] iv) Widowed[3] v) Separated[4] vi) Polygamy[5]

1.5. Education level of household head (years of schooling) ___________________________.

1.6. Number of house the household have_________________________________

1.7.The roof of the house for the household is made up of? i) Grass roofed [0] ii) Corrugated iron roofed [1] iii) Others [2]

1.8. How many hours do you spent for religious and social issues per week? ____.

1.9. Do you participate in any Community Based Organizations (CBOs)? i) Yes[1] ii)No[0]

1.10. If yes, in which of the following Community Based Organizations do you participate?

i) Equib ii) Idir iii) Mahber iv) Debo v) others, specify______________________

1.11. Are you a member of any cooperation? i) Yes [1] ii) No [0]

1.12. If the answer for question number 1.11 is yes, what benefit you obtained being a member?____

1.13.Please, provide genuine information for each of your household member's information

No	Name of the household member	Age	Sex	Years of education	Disability	Relationship to the household	Religion
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							

Codes:Sex Male[0], Female[1]	Education level indicates Years of education for educated one and, 0 otherwise.	Codes:Disability Disable[0], Non-disable[1]	Codes: Relationship to household head Household head[0] Wife/husband[1], Son[2],Daughter[3], Other [4]	Codes:Religion Christian[0], Muslim[1], Others[2]

Part II. Farming characteristics

2.1. How many plots of land do you own? ________________________________

2.2. Have you rented out your plot to others especially to share croppers on the basis of typically sharing half of the production from the rented plot? a) Yes [1] b) No [0]

2.3. If yes, what is your reason for renting out land? (Multiple responses are possible)

i) Health problem ii) Lack of seed/inputs iii) The availability of extra land iv) Female household heads v) Elderly/lack of labour strength vi) Others, specify ___________

2.4. Have you ever share cropped in land from others? i) Yes[1] ii) No [0]

2.5.How long have you been farming? _______________ Years.

2.6. Kindly indicate the ownership type of the land you cultivate (multiple choice possible) a) Individual [0] b) Family [1] c) Rented in [3] d) shared in [4]

2.7. Do you face labor shortage? a) Yes [1] b) No [0]

2.8. If the answer is yes, what is the reason?_______________________________________

2.9. Do you face any natural risk like heavy rain, animal or crop disease? a) Yes [1] b) No [0]

2.10. If the answer is yes, how much you lose estimated value in birr?___________________

2.11. How do you perceive fertility of your land? a) fertile b) medium c) less fertile

2.12. What was the trend of your household land holding size since the last ten years?

a) Increasing [1] b) Decreasing [2] c) No change [3]

2.13. If decreasing/ increasing what was the reason?

Specify______________________________

2.14. What constraints affect your land productivity ? (multiple response possible)

i) erosion [0] ii) poor soil fertility[1] iii) water scarcity[2] v) highly sandy[3]

2.15. Do you undertake any mechanism to minimize soil erosion/ land management practices in your own farm? i) Yes[1] ii) No[0]

2.16. If yes, which of the following measure(s) do you practice to minimize soil erosion on your own farm? (multiple response possible) i) terracing[0] ii) tree planting[1] iii) Stone bunds [2] iv) counter ploughing [3] v) others, specify______________________

2.17. Which of the following land management practices do you carry out in order to maintain

and replenish the soil fertility of your farmlands? (multiple response possible)

i) field rotation [0] ii) crop rotation [1] iii) manuring [2] iv) using fertilizer[3]

v) others, specify____

2.18. Please indicate the following farm inputs whether you used or not used in 2014/2015.

Farm inputs	Amo unt	Used[1], not used[0]	List the crops if used
Improved seed			
Fertilizer			
Agrochemicals			
Veterinary drugs			
Livestock concentrates			

2.19. Land area cultivated for crops by hectares and respective output obtained in quintals.

Kindly provide information on the following crops (only on those you have produced).

Type of Crops	Plot size by		Outputs		Seed used		Labor force used		Oxen-pairdays	fertilizer	
	Tima d	Ha	Quint al	Kg	Kun a	kg	Famil y	Hir ed	timad	ku na	kg
Teff											
Wheat											
Barely											
Sorghum											
Beans											
Peas											
Lentil											
Bean											
Sesame											
Noug											
Tomato											
Potato											
Cabbage											
Onion											
Pepper											
Carrot											
Orange											
Lemon											
Banana											
Others											
Total											

Code for Soil fertility (0=infertile, 1= medium and 2=fertile)

Code for land ownership (0=own, 1=shared in and 2= rented in)

2.20. Kindly indicate how many livestock you own and also provide other related information.

No	Type of animal	Num bers	How many if you want to Sell in 2014/2015	If there is any sold animal	
				Number of Sold	Income gained (Birr)
1	Cows				
2	Calves				
3	Heifers				
4	Bulls				
3	Oxen				
4	Mule				
5	Donkey				
6	Horse				
7	Goat				
8	Sheep				
9	Hen				
	Bee hives				
				Total	

2.21. Kindly indicate how many outputs you obtained with respective unit of measurements and also provide other related information.

No	Commodity type		Amount produced (lit, kg, no)	How much it cost now (Value) in ETB
1	Dairy out put	fluid milk		
		Butter		
		Cheese		
2	Poultry	Egg		
		Chicken		
3	Honey bee	Honey		
		Bees wax		
		Bee colony		
4	Animal by-products	Hide and skin		
		Manure/Dung		
			Total	

2.22. Which of the followings are the constraints to rearing livestock? (Multiple response are possible) a) Shortage of grazing land[1] b)Lack of additional fodder[2] c) Disease prevalence [3] d) Insufficient veterinary services [4] e) Shortage of water [5] f) Attack by wildlife [6] g) others, specify_______________________________

Part III. Non-farm activities (non-farm employment opportunities)

3.1. Do any member of your family has involved apart from crop production and livestock rearing in this year (2014/2015 production season)? a. Yes [1] b. No [0]

3.2. If the answer for question number 3.1 is yes, in which of the following activities that any of your household members are engaged in?

No	Non and off-Farm activities engaged in	Number of participants	Amount gained in ETB
1	Working on other's farm		
2	Renting animals, materials or other things for others		
3	Daily laborer on construction		
4	Self employment in manufacturing e.g. Artisan (blacksmith, weaving, pottery etc)		
5	Sales of wood (Charcoal), local drink, stone/sand, and others		
6	Salary from temporary or permanent employment		
	Total amount non and off-farm income		

3.3.Do you have remittance, aid, gifts/donations from any sources in this production year?

a) Yes [1] b) no [2] if the answer is yes, how much?____________________

3.4.For what purpose (s) do you or others in your household use the earnings obtained from non-farm employment activities? Identify the three main objectives in their order of importance.

Purposes	Yes[1], No[0]	Rank
To buy food/ cloth		
For saving		
To buy modern farm inputs(fertilizer, improved seed, insecticides etc) and farm tools		
Build a house		
Pay loan/ tax		
Others specify		

3.5.If none of your household members work in non-farm activities what are the reasons for failing to participate in the activities?

Reason for not working	Yes [1], No[0]
Lack of spare time from agriculture	
Lack of awareness about its contribution	
Lack of work skill	

Lack of job opportunities	
Unable to work due to old age	
Health problem	
Lack of start-up capital	

Part IV. Living standard of the household

4.1.Do you face food shortage? a) yes [1] b) no [2]

4.2. If the answer for question number 4.1 is yes, what is the reason you face this problem?

a. Shortage of family labor [0] b. Shortage of seed and credit access [1] c. Lack of oxen [5]

d. Shortage of farm land[2] e. Shortage of rain [3] f. Small amount usage of fertilizer [4]

4.3. Have there been times in the past twelve months when you did not have enough money.

	Yes[1], No[0]
To buy food that your family needed	
To provide adequate shelter or housing for your family	
To purchase modern farm inputs	
To cover the cost of education, health care etc	
Others specify	

4.4. Have there been times in the past 12 months when you or your family have gone hungry?

i) Yes [1] ii) No [0]

4.5. Do you meet the all year round food requirements of your household members from own production? i) Yes ii) No

4.6. If you are not self-sufficient, for how many days/months does your family faced food shortage?(And mention name of months)____________________________________

4.7.Does the income you earn from non-farm activities enable you to buy food for bridging the food deficiency? 1. Yes 2.No

4.8.According to your own self-assessment, is your household

i) Food secure[0] ii) Food insecure[1] iii) Varies from one year to another

4.9.What do you think are the main reasons for being food insecure?

Reason for food insecurity	Yes[1], No [0]
Inability to produce sufficient grains and to rear livestock	
Meager income from non- farm activities	
Instability due to frequent changes in rural policies	
Failure to properly utilize own production and other earnings	
Drought and adverse weather patterns	
High price of food	
Others specify	

4.10. Over the past five years, what can you say about the annual temperature in your local area? i)Warmer [0] ii) Colder [1] iii)Stayed about the same[2]

4.11. Over the past 5 years, would you say the precipitation (rainfall) in your local area?

i) Increased a great deal [0] ii) Stayed about the same [1] iii) Increased a little [2]

v) Decreased a great deal [3]

4.12. In the area where you currently live, would you say there was enough rainfall for growing

crops or livestock during the last growing season? i) Yes [1] ii) No [0]

4.13. In the next 12 months are you likely or unlikely to move away from the area where you live? i) likely to move[0] ii) Unlikely to move [1]

4.14. Do you think your living condition has improved or worsened as compared to what it used to be five years ago? i) Better off [0] ii) slightly improved [1]

iii) No change [2] v) Worse off [3]

Part V. Institutional/service factors (credit, extension and other service)

5.1. Do you use ICT like radio or mobile phone to obtain agricultural information?

a) No [0] b) Yes [1]

5.2.If the answer for question number 4.1 is yes, which of them you or your household used?

i) Mobile phone [0] ii) Radio [1] iii) Television [2] others specify_________________

5.3. Are you irrigation user? a) No [0] b) Yes [1]

5.4. If the answer is No,what was the reasons not using irrigation?

a. sufficient rain and moisture[2] b. No farm land in surface water access [0]

c. No awareness about it [1]d. Others [3]

5.5. How long do you use irrigation farming? ______________years

a) No irrigation before [0] b) 0-3 years [1] c) 4-6years [2] d) 7 and above years [3]

5.6. Did you have credit for the production of your agricultural products? a.Yes[1] b. No [0]

5.7. If the answer for question number 5.6 is yes, how much_______________________

5.8.What is the source of your credit? a. Banks [1] b. Friends[2] c.Traders [3] d.Microfinance [4]

5.9. For what purpose you used the credit? a) Buying fertilizer and improved seeds [0]

b) Renting land [1] c) buying animals [2] d.) others specify_______________________

5.10. Is credit timely and adequately available for agricultural commodities development?

a. No [0] b. Yes [1]

5.11. Did extension staff visit you in this growing season to give you farm advice?

a) Yes [1] b) No [0]

5.12. If yes, how many times did extension staff visit you this cropping season? __________

5.13. If yes, did you gain any knowledge from the extension agents that could help you to do things differently on the specific improvement? a) No [0] b) Yes [1]

5.14. Are you member of any cooperation? a) No [0] b) Yes [1]

5.15. If the answer for question number 5.14 is yes, what you get being a member?____

5.16. How far do you travel to get health service? _________________________________km

5.17. Is there sever health problem in the household in this production season?

a) yes[1] b)no[0]

5.18. If the answer for question number 4.17 is yes, do you incurred any cost for medication? a)Yes [1]b) No [0] if the answer is yes, how much________________________

5.19. How far do you travel to get the main local market ___________________________km?

5.20. Do you get market information about prices and demand condition of agricultural inputs and outputs? a. yes [1] b. no [0] If yes indicate the source___________________

5.21. How far do you travel to get the nearest school ______________________________km?

5.22. How many kilometers your area are away from the woreda town? _______________km

5.23. How do you describe the type of road in your locality? a) Gravel road[1]

b) Asphalt road [2] c) Muddy road [3] d) Others specify____________________

5.24. Would you tell me about the transportation facility in the area? a) Very hard to get transport [1] b) there is no problem of transportation[2] c) others specify____

5.25. Do you think that the transportation problem affect your farming and non-farming economic activity? a)yes [1] b) no [0]

5.26. If yes how did affect? a) Delay to reach on time[1] b) perishable goods might spoil before they reach market[2] c) Others specify_____________________________________

5.27. Land area cultivated for crops by hectares and respective output obtained in quintals. Kindly provide information on the following crops (only on those you have produced).

Type of Crops	Soil fertility	Improved seed	Agro chemical		Plot size by		outputs		Seed used		Labor force used		Oxen-pairdays	fertilizer	
			herbicide	Pesticide	Timad	Hectare	Quintal	Kg	Kuna	kg	Family	Hired	Timad	kuna	Kg
Teff															
Wheat															
Barely															
Sorghum															
Beans															
Peas															
Lentil															
Bean															
Sesame															
Noug															
Tomato															
Potato															
Cabbage															
Onion															
Pepper															
Carrot															
Orange															
Lemon															
Banana															
Others															
Total															

Code for :Soil fertility (0=infertile, 1= medium and 2=fertile), land ownership (0=own, 1=shared in and 2= rented in)

Code for: Improved seed (user=1, non-user=0), herbicide (user=1, non-user=0), pesticide (user=1, non-user=0)