ECONOMIC EFFICIENCY OF SMALLHOLDER MAJOR CROPS PRODUCTION IN THE CENTRAL HIGHLANDS OF ETHIOPIA

ESSA CHANIE MUSSA

A thesis submitted to the Graduate School in partial fulfilment for the requirements of the award of the Masters of Science Degree in Agricultural and Applied Economics specialization in Agricultural Policy and Trade of Egerton University

EGERTON UNIVERSITY

June, 2011

DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not, wholly or in part, been presented for the award of any other degree in this or any other University elsewhere.

Mr. Essa Chanie Mussa

Sign: ________________

Date: ________________

RECOMMENDATION

The thesis has been submitted with our approval as Supervisors:

1. **Prof. Gideon A. Obare**

   Department of Agricultural Economics & Business Management,

   Egerton University, Kenya

   Sign: ____________________

   Date: ____________________

2. **Prof. Ayalneh Bogale**

   African Centre for Food Security Studies,

   University of Kwazulu Natal, Pietermaritzburg, South Africa

   Sign: ____________________

   Date: ____________________

COPYRIGHT

ACKNOWLEDGEMENTS

All Praises are to Allah, The AS-SAMAD, Lord of the Heavens and the Earth, for giving me the strength and capacity to undertake my study and for His help in all aspects of my life during my stay at Egerton University (Kenya) and University of Pretoria (South Africa). I am thankful to my parents for their love and moral and material support throughout my study.

I am deeply indebted to my major advisor, Professor Gideon A. Obare for his guidance and encouragement throughout my study. I am very much grateful to him for the constructive advices and comments, patience and providing me the freedom to think independently and reasonably throughout my proposal and thesis work. I am also very much thankful to him for facilitating the attachment to undertake the study with ICRISAT-Legume Project. This thesis would not have been completed this way without his dedicated support.

I am also equally indebted to my co-advisor, Professor Ayalneh Bogale, for his invaluable guidance, advice and constructive comments throughout my work. I am also grateful for his suggestions, directions and tireless effort for the betterment of the work.

It is also my pleasure to forward my heartfelt gratitude to Dr. Franklin P. Simtowe of The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) for his constructive comments and advice. I also deeply thank Dr. Solomon Asfaw, while he was in ICRISAT, for providing me the data set for this study.

It is my honor to forward my heartfelt gratitude to German Academic Exchange Service (DAAD) for granting me the scholarship to pursue my study at Egerton University. Equally important, my special thanks go to African Economic Research Consortium (AERC) for facilitating my scholarship and transfer of funds from DAAD, award of the research fund and giving me an opportunity to attend the Shared Facility for one semester at the University of Pretoria, South Africa.

I am also grateful to all staff members of Gimbichu, Lume Ejere and Minjar Shenkora districts Agricultural and Rural Development Offices for providing me the required district related information.

Last but certainly not least, my special thanks go to head of the department, Dr. B.K Mutai and all other staff members and colleagues of the department of Agricultural Economics and Agri- Business Management of Egerton University for their caring support throughout my stay.

ABSTRACT

Despite the policy interest of the Ethiopian government to expand *teff* (*Eragrostis tef*), wheat and chickpea production for exports, domestic consumption and food and nutritional security for the rural poor the production system is not adequately market-oriented and productivity is at its lowest level. Besides, there is dearth of information on how limited resources in crops production are being used so as to optimize outputs in the country. Thus, this study was conducted to assess resource use efficiency and subsequently to determine the underlying factors which affect inefficiencies in the production of *teff*, wheat and chickpea by smallholder producers in the central highlands of Ethiopia. Cross-sectional data from a baseline survey conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Ethiopian Institute of Agricultural Research (EIAR) were used. Multistage sampling procedure was used to select a random sample of 700 smallholder crop producers from three districts namely Minjar-Shenkora, Gimbichu and Lume-Ejere. Using Data Envelopment Analyses (DEA) approach, the study established that smallholder farmers in the study areas are technically, allocativelly and economically inefficient with mean technical, allocative and economic efficiency scores of 0.79, 0.43 and 0.31, respectively. A One-Way ANOVA and Kruskal Wallis tests established that there is a significant variation in resource use efficiency across districts. Furthermore, a two- limit Tobit regression model results revealed that while family size, farming experience, credit access, walking distance to the nearest main market, and total own land cultivated during the long rainy season affect technical inefficiency positively and significantly; age of household head was found to have a negative and significant influence on technical inefficiency. The results also showed that whereas economic inefficiency was positively and significantly affected by family size, farming experience and membership to associations; for household heads having a role in their community contributed negatively and significantly to economic inefficiency. Moreover the study results also showed that about 37 percent of the farmers in aggregate operate under decreasing returns to scale. Based on the findings of the study policy implications for improvements in resource use efficiency and productivity were drawn.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ADLI	Agriculture Development- Led Industrialization
AE	Allocative Efficiency
ANOVA	Analysis Of Variance
BCC	Banker, Charnes and Cooper (1984) DEA model
CCR	Charnes, Cooper and Rhodes (1978) DEA model
CRS	Constant Return to Scale
DEA	Data Envelopment Analysis
DEAP	Data Envelopment Analysis Program
DMUs	Decision Making Units
DRS	Decreasing Returns to Scale
DZARC	Debre Zeit Agricultural Research Centre
EE	Economic Efficiency
EIAR	Ethiopian Institute of Agricultural Research
ETB	Ethiopian Birr (Currency)
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GoE	Government of Ethiopia
Ha	hectare
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFA	International Fertilizer Industry Association
IFAD	International Fund for Agricultural Development
ILCA	International Livestock Center for Africa
IRS	Increasing Returns to Scale

Kg	kilograms
MDGs	Millennium Development Goals
ML	Maximum Likelihoods
Mm	Millimeters
MoARD	Ethiopian Ministry of Agriculture and Rural Development
MVP	Marginal Value Product
SE	Scale Efficiency
SPF	Stochastic Production Function
TE	Technical Efficiency
TEcrs	Technical Efficiency under the assumption of Constant Returns to Scale
TEvrs	Technical Efficiency under the assumption of Variable Returns to Scale
UN	United Nations
VRS	Variable Return to Scale

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Agriculture is the basis of Ethiopian economy which accounts for half of the country's GDP, 60% of its exports and 80% of total employment (CIA, 2007; Tewodros, 2009). The undeveloped market economy, which started during imperial period (1930-1974), was halted during the military regime (1974-1991) that introduced command economy. However, since the current government took power in 1991, Ethiopia has been pursuing a market- oriented development strategy and implementing policies that began the shift from a state-controlled to a free market economy. The government has embarked on a various programs of economic reform, including trade liberalization, privatization of public enterprises and streamlining the bureaucracy (Birega, undated). The current Ethiopian economic development strategy, Agriculture Development-Led Industrialization (ADLI), identifies the growth of agriculture as a key to the development of other sectors as well (Admasu and Paul, 2010).

Ethiopian economy is largely dominated by subsistence agriculture and it is smallholder-based (Bishaw, 2009). Moreover, mixed farming dominates the Ethiopian highlands. The smallholder farmers in the Ethiopian highlands are poor; individual land holding ranges between 0.5 and 2.5 ha; family sizes are large; land productivity is low and food requirements are not fully met (Jabbar *et al.*, 2000). Ethiopian highland agriculture is characterized by high dependency on rainfall, traditional technology, high population pressure and the lowest productivity level (Medhin and Köhlin, 2008). The cereal-based farming systems have also remained largely unchanged and thus have become unable to sustain the ever increasing population with food and energy demands. As a result, there is severe land degradation and declining productivity in many areas of the highlands (Ayele, 2008).

According to Gebremedhin *et al.* (2006) the development of the Ethiopian economy heavily depends upon the rate at which agricultural growth is achieved. This growth, in turn, depends on the rate at which the current subsistence oriented agricultural production system is transformed into a market oriented production system. This transformation process of the agricultural production system forms the basis of the agricultural development strategy of the

Government of Ethiopia (GoE). On the other hand, rapid agricultural growth in Ethiopia is expected to have significant benefits for the poor. Achieving agricultural growth of six percent per year from year 2005/06 to 2015 would reduce national poverty from its 40.0 percent in 2005/06 to 18.4 percent by 2015 (IFPRI, 2009).

According to Alema *et al.* (undated), the appropriate type of information required to support agricultural sector development in any economy depends on the stage of its development. In the early stage of its development the need focuses on technical information on crops and production conditions. At a later stage socio-economic information requirements are added such as farm structure, costs of production and farm income levels. In further developed agriculture sectors issues such as food safety, quality and social and environmental standards including fair trade and CO2 emissions are added. This variation in need of information implies that the business environment of agric-food production is very dynamic, driven by various and changing needs of consumers and society.

The government of Ethiopia has put high priority to the development of export-oriented and commercial agriculture, such as horticulture, oil seeds, livestock, dairy and agricultural processing. Various facilitating policies are in place or are being developed (ibid). Thus, agricultural policy makers in Ethiopia need to have insight in the potential production capacity, the actual production and trade flows among others. Therefore, adequate information on resource use efficiency and agricultural productivity; information on production and farm income of smallholder farmers are necessary to make the right decisions in policy concerning agricultural development and food security.

The Ethiopian Ministry of Agriculture and Rural Development (MoARD) has developed and released (in 2004) a master plan to enhance market- oriented production for priority crops (wheat, barley, *teff*, lentil, chickpea, cotton, sesame, coffee and spices) and livestock (dairy, meat, poultry, apiculture, sericulture, fisheries, skins and hides) commodities. This master plan incorporates various objectives such as developing a plan to enable the use of modern technologies to efficiently optimize production and productivity (at least doubling productivity of major crops), encourage selected districts to specialize in one or two export commodities and make competitive in the international market and alleviate local food shortage (MoARD, 2004).

In the plan, it has been also identified that area under *teff* cultivation is the largest but its productivity is the lowest among cereal crops. Moreover, much of the produce is consumed locally. However, *teff* has become one of the export commodities since 1999 and the main importers are Israel, USA, Djibouti, Saudi Arabia and Switzerland (MoARD, 2004). Although Ethiopia produces wheat, the country is a net importer of the commodity (MoARD, 2004). Chickpea is one of the major legumes grown in Ethiopia, mainly by smallholder farmers usually under rain fed conditions. It is one of the main annual crops in Ethiopia both in terms of its share of the total legumes cropped area and its role in direct human consumption. It is largely grown across the highlands and semi-arid regions of the country (Bejiga *et al.*, 1996 cited in Shiferaw and Teklewold, 2007). However, competitiveness of smallholder chickpea producers is restricted by low productivity and poor quality of traditional varieties in the country (Shiferaw and Teklewold, 2007).

Moreover, the application of chemical fertilizer and improved seeds is quite limited despite Government efforts to promote the adoption of modern and intensive agricultural practices (Chanyalew *et al.*, 2010). There is limited access by smallholder farmers to agricultural inputs, financial services, improved production technologies, irrigation and agricultural markets. These problems combined with poor land management practices have led to severe land degradation. Land degradation is further exacerbated by overgrazing, deforestation, population pressure and inadequate of land use planning. Moreover, expansion of the cropped area to more marginal lands has led to severe land degradation in some areas (ibid).

Therefore, one key policy question is as why this is the case. Any attempt at answering this question requires knowledge on how economically efficient smallholder *teff*, wheat and chickpea producers are in the production process in order to identify the potential production capacity of these crops.

1.2 Statement of the Problem

Despite the policy interest to expand crop production for exports, domestic consumption and food and nutritional security for the rural poor as well as availability of sufficient rainfall, Ethiopian highlands farmers are experiencing very low levels of productivity. The smallholder farmers in the Ethiopian highlands are poor, individual land holding ranges between 0.5 and 2.5 hectares, large family sizes, land productivity is low and household food requirements are not fully met. The smallholder cereal-based farming systems have also remained traditional (peasant) and non-commercial oriented. Thus, the system is unable to sustain the ever increasing population with food and energy demands. As a result, there is severe land degradation and marginality of agricultural lands hence declining productivity in many areas of the highlands. Therefore, an ever increasing population pressure and environmental degradation followed by declining productivity and expansion of marginal agricultural lands necessitates farmers either to use modern technologies or need to use resources efficiently in order to optimize outputs in the country. Moreover, there is a dearth of information on the level of resource use efficiency in smallholder crop production and the associated key determinants of inefficiencies. Therefore, this study attempted to fill the existing knowledge gap by addressing issues related to economic, technical and allocative efficiencies of smallholder crop production in the central highlands of Ethiopia by providing empirical evidence on smallholder resource use efficiency.

1.3 Objective of the Study

The main objective of this study was to assess smallholder crops production resource use efficiency in the central highlands of Ethiopia.

The specific objectives were:

1) To describe the socio- economic and production characteristics of smallholder major crop producers in the study areas;
2) To estimate farm level economic, technical and allocative efficiency of smallholder *teff*, wheat and chickpea production; and
3) To identify and categorize factors affecting the level of technical and economic inefficiencies in smallholder *teff*, wheat and chickpea production processes.

1.4 Hypotheses of the Study

1) There is no significant variation in the output of crops across districts regardless of producers' socio economic and institutional differences,
2) Smallholder farmers are resource use efficient; hence there is no room for further increase in output or reduction in cost of production, and
3) Following 2), demographic, socio-economic and institutional factors have no significant influence on the inefficiency of smallholder farmers in the study areas,

4) There is no significant difference in influence of demographic, socio economic and institutional factors on both technical and economic inefficiency levels,
5) There is no significant difference in the distribution of efficiency scores of smallholder farmers across districts in the study areas,
6) Smallholder crop producers in the study areas operate under constant returns to scale portion of their production function.

1.5 Justification of the Study

Knowledge on overall efficiency would provide useful insights into competitiveness and comparative advantage of the smallholder farming and potentials for increasing productivity and resource use efficiency which is a top policy priority of Ethiopian government.

The empirical evidence from the study is essential for both governmental and non-governmental organizations to carry out successful rural development interventions. Findings of the study will guide policy makers towards better and more informed decision-making for rural development and consequently enhance the achievement of the national goals of reducing poverty and achieving food security in the highlands of the country.

An adequate understanding of the factors that affect inefficiency of farmers is significantly important for informed decision and transfer of the recommended practice to reduce or eliminate inefficiency. It is also important for researchers and policy makers in various aspects. The information will assist researchers for developing appropriate technologies that better fit the needs of smallholder farmers to improve resource use efficiency hence production and productivity; and policy makers will also benefit from the information to formulate appropriate policies, strategies, programs and interventions that help to increase crops production and productivity. This, in turn, will enable the achievement of government targets for crop yields that would make it possible for the economy to attain and sustain the six percent agricultural growth target during 2006-2015 which will enable the reduction of national poverty to 18.4 percent by 2015. The empirical evidence provided has identified ways and extents of yield improvements in major crops. This does not only benefits farm households directly, by increasing incomes from agricultural production, but also by allowing farmers to reduce their resource use to major crops production and diversify their resource allocation towards other higher-value crops that lead to market oriented production.

Moreover, the findings would help the government to achieve the first MDG goal, to eradicate extreme poverty and hunger, and the national objective aims to sustainably increase rural incomes and national food security, which in particular depend on raising productivity of agriculture through efficient and sustainable resource use.

1.6 Scope and Limitation of the Study

This study estimated economic, technical and allocative efficiency scores of only major crops production which included *teff*, wheat and chickpea for selected sample farmers. It used one production year cross sectional data and its generalization was made for smallholder crop producers in the central highlands of Ethiopia.

1.7 Operational Definition of Terms

- **Allocative Efficiency:** efficiency refers to the ability to produce at a given level of output using the cost minimizing input ratios (Farrell, 1957);

- **Economic Efficiency:** is the capacity of a firm to produce a predetermined quantity of output at minimum cost for a given level of technology (Farrell, 1957);

- **Household:** it comprises either one person living alone or a group of people, who may or may not be related, live (or stay temporarily) in the same address, who either share at least one meal a day or share common living accommodation (Jenkinson, 1998).

- **Smallholder Farmer:** Often cultivate less than 1 ha of land in favorable areas and high population densities, whereas they may cultivate 10 ha or more in semi-arid areas (Dixon *et al*., 2004).

- **Technical Efficiency:** the ability to produce maximum output (along the isoquants) given the level of technology, and production inputs (Farrell, 1957); and

- ***Teff* (*Eragrostis tef*):** a cereal with very fine grains endemic to Ethiopia (Nyssen *et al.*, 2008).

CHAPTER TWO

LITERATURE REVIEW

2.1 Environmental Degradation and Marginality in the Ethiopian Agriculture

Environmental and resource degradation has been widely accepted as a crucial constraint to reducing poverty among the most disadvantaged and marginalized populations in the world, who are largely rural (UN Millennium Project, 2005). Moreover, poverty and environmental degradation tend to be more pronounced in the so-called least favored areas or zones of marginal agricultural production. These are areas which have the weakest natural resource endowments, the least political power, and are the most remote from markets. Moreover, least favored areas are areas at risk of getting stuck in a poverty trap which prevents them taking advantage of emerging opportunities (ibid).

According to Pender *et al*. (2001) there is a strong interrelation between problems of poverty, low agricultural productivity, and natural resource degradation in less-favored areas of the tropics. However, addressing the complex challenges of less-favored areas will not be easy or inexpensive. More critically, it requires policy and institutional reforms; investments in agricultural research; development in rural infrastructure and the active involvement of local communities are among others. The authors further explained that ecological and geographic constraints of location are major contributors to the spatial concentration of rural poverty. Indeed, most of the rural poor worldwide are found in those least favored areas where natural and human factors combine to constrain agricultural production and market access (ibid).

Anage (undated) indicated that in Ethiopia the problems of widespread land degradation in all regions combined with recurring drought constitute one of the most serious problems facing the country's agriculture. It is more pronounced particularly in the highlands where most agricultural production takes place. It is also further mentioned that while more than 85 percent of the land is moderately to very severely degraded, about 75 percent is affected by desertification.

In the Ethiopian highlands the problem of land degradation stems mainly from poor land-use practices and population pressure (ibid). The production system in the highlands is mainly rain fed, subsistence-based and smallholder-oriented. Furthermore, population and livestock pressures have decreased the size of land holdings, including both arable and pasturelands, leading to conversion of forested and marginal areas into agricultural lands and low level of crop productivity (Hoekstra *et al.*, 1990 cited in Bishaw, 1993; Bishaw, 1993; Anage, undated). In Bishaw (1993) it is also indicated that soil degradation in Ethiopia is a direct result of past agricultural practices in the highlands. Some of the farming practices within the highlands encourage erosion. These include cultivation of cereal crops such as *teff (Ergrostis tef)* and wheat (*Triticum sativumt*) which require the preparation of a finely tilled seedbed, the single cropping of fields, and down-slope final plowing to facilitate drainage.

The trends of agricultural growth in Ethiopia are heavily reliant on expansion of agricultural land (extensification) and limited intensification through irrigation. For instance, IFAD (2009) indicated that in Ethiopia, while the cultivated area per capita declined, the total cultivated area expanded which explains the positive growth in total cereal production during the last decade. However, during the same time, both agricultural land and labor productivity has showed a declining/stagnant trend. The underlying forces were population growth which has driven cultivated area expansion into fragile and marginal lands resulting in soil loss, mining of soil nutrients, and deforestation (ibid). On the other hand, a study by Awulachew (undated), using a data during the period 1980-2001, shows that cereal production growth, which was at an average annual value of 0.74%, mainly comes from cultivated land growth (land expansion) at 0.57% and productivity growth (yield increase) of 0.17%. However, on the other hand, the average population growth of Ethiopia was at approximately 2.1% in the same period. The result shows that production growth is below population growth. Given that majority of the population live in the highlands and marginal areas, the former pushes agriculture to encroach more and more to less productive, highly vulnerable to degradation and high gradient marginal lands. However, the author also indicated that recent reports of government sources particularly after the 2002/2003 drought show that productivity of agriculture has increased over 6% per annum (ibid).

The problem of land degradation, population pressure and the resultant low level of crop productivity in the agricultural production have a vicious cycle type of relation. According to Mengistu and De Stoop (2007), the growing population has led to shrinkage of land available for agriculture. This is further exacerbated by the loss of farmland due to land degradation. This leads to an increasing demand for agricultural land, which usually ends up in converting more forest land into farmland/grazing land. The authors also indicate that many farmers (probably the poorest) use areas that are highly susceptible to degradation which should not be used for agriculture at all. Moreover, once the productivity of their land falls below acceptable levels, they move to new, mostly forestland that is marginal for agriculture until they have to move again looking for better productive areas (ibid). Similarly, Asfaw (2003) also mentioned that encroachment into forest and protected areas, including to marginal lands, causes accelerated land degradation resulting in a self-propelling downward vicious cycle of degradation of the natural resources, leading to declining crop yields then to expansion of cultivated lands. Again this leads to further natural resource degradation and to further decline in crop yields. Thus, this self-propelling degradation of resources substantially contributes to rural poverty and famine vulnerability.

From the preceding discussion it is clear that intensification of agricultural land use must be accompanied by technological innovations and resource use efficiency that will lead to increased agricultural production and productivity. Hence, it brings development both at the margin/less favored areas and the resource rich/advantageous areas. Improvements in resource use efficiency and increase in productivity will reduce further expansion of smallholder farmers to the marginal agricultural areas and hence protects the resource base of the poor against degradation. Therefore, a resource use efficiency study remains essential to broaden the range of responses and options available for farmers and to increase yields of staple crops given current level of resources at hand. It would help to effectively respond to the question of how poor and marginalized rural people can improve their living conditions and the productivity of their resource base.

2.2 Efficiency in Agricultural Production

In economics, the term efficiency is commonly used in a variety of settings which includes aspects such as efficient price, efficient markets and efficient firms among others. Efficiency in production refers to scarce resources being used in an optimal fashion. In production economics, efficiency can be understood in terms of a firm's ability to convert inputs into outputs and respond optimally to economic signals or prices.

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 (Ali, 1996; Udoh, 2000; Hailu *et al.*, 2005). For these reasons, 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 (for example, Hailu *et al.*, 2005; Ozkan *et al.*, 2009 and Ghorbani *et al.*, 2009 among others) and policy makers alike. 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. Moreover, for determination of efficiency of a particular firm, there is a need for efficiency measurement through the production factor inputs and processes (Omonona *et al.*, 2010).

It is impossible to get identical yields with utilization of completely equal amount and quality of inputs. There are discrepancies in the amount and values of inputs and outputs as well as profit ratios of producers (Kumbhakar and Tsionas, 2006). These discrepancies in productive efficiency of producers mainly stem from differences in technical qualifications and unfavorable exploitation of resources (ibid). The evaluation of success of the enterprise in terms of effective use of inputs which includes land, labor, seeds, chemicals, water and energy and maintenance of a thorough cost structure lies in the efficiency analysis of the process (Ozkan *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 iso-quant 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. Thus, economic efficiency (EE) can be defined as the capacity of a firm to produce a predetermined quantity output at a minimum cost for a given level of technology.

However, over the years, Farrell's methodology had been applied widely in diverse industries and organizational structures. The methodology was also undergoing many refinements and improvements through major theoretical and empirical research advancements occurred in late 1970's (Hailu *et al.*, 2005). One of such improvements is the development of stochastic frontier model which enables one to measure farm level technical and economic efficiency using maximum likelihood estimate. Aigner *et al.* (1977) and Meeusen and Van den

Broeck (1977) were the first to propose stochastic frontier production function and since then many modifications had been made to stochastic frontier analysis.

According to Okoruwa *et al.* (2006), the measurement of farm specific technical efficiency is based upon deviations of observed output from the best production or efficient production frontier. If a farm's actual production point lies on the frontier it is perfectly efficient. But, if it lies below the frontier then it is technically inefficient. The ratio of the actual to the potential production levels of a farmer defines the level (scores) of technical efficiency (ibid). An economically efficient input-output combination would be on both the frontier function and the expansion path (Ogundari and Ojo, 2006).

According to Ozkan *et al.* (2009) interpretation of efficiency in agriculture is also as important as the evaluation of agricultural outputs with respect to diverse range of inputs used. The researchers further indicated that the process of transformation of inputs to outputs has a vital role in interpretation of success of a production system. The success of the process can be explained through productive or economic efficiency (ibid). Moreover, for all agricultural sectors to remain competitive in the market and be profitable, achieving a high level of technical efficiency is of prime importance (Ghorbani *et al.*, 2009).

Therefore, 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 would help to avoid the expansion of marginal lands in Ethiopia.

2.3 Empirical Estimation Approaches to Efficiency

A number of methods have been developed either parametric (econometric) or non-parametric (mathematical programming) to estimate efficiencies in firms/farms. These include stochastic frontiers which adopt production, cost or profit functions and data envelopment analysis (DEA) and a number of versions of DEA in the efficiency estimation process. According to Mersha (2004), considerations such as the type of data, the underlying behavioral assumptions of firms, the relevance to consider and extent of noise in the data and the objective of the study determine the selection of specific frontier model.

2.3.1. Stochastic Frontier Approach (SFA)

The Stochastic frontier Approach (SFA) was developed independently by Aigner *et al.* (1977) and Meeunsen and Van den Broeck (1977). SFA is a parametric method where the error term is decomposed in a regression model into inefficiency component and measurement error component; $\varepsilon_{ij}=v_{ij}-u_{ij}$ where ε_{ij} is the error term, v_{ij} the measurement error, and u_{ij} the inefficiency component. The model 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). SFA approach can be extended to measure inefficiencies in individual production units based on some distributional assumptions for the u_{ij} on the technical and economic inefficiency scores. These assumptions are based on functional forms used in the analysis; half normal distribution for Cobb-Douglas forms, truncated normal for Trans-logarithmic forms and exponential distribution for generalized Leontief models (Mbaga *et al.*, 2003). The models for SFA allow for estimation of standard errors and tests of hypotheses using maximum likelihood methods which cannot be possible with deterministic models because they violate certain maximum likelihood assumptions (Jondraw *et al.*, 1982 and Ali and Flinn, 1989). However, a serious shortcoming with SFA is that there is no priori justification for the selection of any particular functional form for the inefficiency component. In parametric frontier methodology the selection of specific functional form may not represent the reality (Mersha, 2004). Moreover, Coelli *et al.* (1998) indicated that the SFA is appropriate for single-output technologies; unless cost-minimizing objective is assumed.

2.3.2. Data Envelopment Analysis (DEA)

Data envelopment analysis (DEA) is a linear programming technique developed in the work of Charnes, Cooper and Rhodes (1978). It uses deterministic frontier models based on linear programming techniques to estimate technical efficiencies for each production unit non-parametrically (Banker *et al.*, 1984). The approach measures the efficiency of a decision making unit relative to the efficiency of all other decision making units subject to the restriction that all decision making units are on or below the frontier. The DEA is a systems approach; it is appropriate to estimate technical efficiency when input prices data is not available and accounts for multiple inputs and outputs simultaneously thus the efficiency estimate is more consistent. The approach identifies underutilized inputs and under produced outputs. However, it has a major weakness in that an assumption is made that all deviations from the frontier are a result of inefficiencies; no account is taken for measurement errors and the noise effect on the frontier (Coelli and Prasada, 2003). On the other hand, the technique requires standard formulation of DEA linear program for each DMU. It is also computationally intensive when the number of DMUs is large (Raju and Kumar, 2006). In addition, incident factors, variation of organization structure, climate, geographical location, soil type, economic conditions and measurement errors are not considered in the DEA method. Therefore, accurate data which is free from measurement errors in variables of homogenous DMUs should be employed in the analysis, and the results should be investigated in depth through field studies (Yilmaz and Harmancioğlu, 2008).

2.3.2.1 Zero data in the DEA

The basic DEA models were initially developed taking in to account that all the data points in the analyses are positive. However, there are situations where this assumption may not hold. In situations where there is variation in technology and managerial qualification between DMUs as well as due to missing data researchers can find that some data may be zero or even negative. However, despite such circumstances the treatment of zero data has not received as much attention perhaps as it should. But, zero data should be treated with caution in assessments rather than resorting to the convenience of simply replacing zero values with some arbitrary positive values (Thompson *et al.*, 1993; Fried *et al.*, 2008). Zeros may be the result of a conscious management decision not to use some inputs or not to produce some outputs, or they may be the result of missing data that could have been replaced by zeros. One needs to establish first which one of these cases represent the zero data and treat them accordingly.

Zero outputs: According to Kuosmanen (2002) treating an output as zero yields for the DMU exactly the same efficiency score as if it was assessed only with the outputs whose values are greater than zero. However, the implications of zeros in outputs differ from those in inputs. Fried *et al.* (2008) also mentioned that zero outputs are not a problem in standard efficiency models such as the CRS or VRS model, irrespective of the model orientation. As further noted by Kuosmanen (2002), the main point to note is that the radial efficiency score does not have a meaning for the zero output when one uses radial output models to assess units with zero output data. That is, it is impossible to radially expand a zero output to a positive output. Moreover, the author also indicates that a zero output value forces the DMU to assign a zero weight to that output. Therefore, the resulting radial efficiency measure is the same as one would obtain if the output concerned was not used in the assessment of the DMU at all. Therefore, according to Fried *et al.* (2008), if one wishes to ignore the output on which the DMU has a zero value, radial efficiency measures should be used. This enables a DMU to reflect radial expansion of outputs or radial contraction of inputs when these inputs and outputs are different from zero. However, if the objective is to reflect the inefficiency resulting from a DMU not producing one of the outputs, non-radial models should be used. Thus, zero outputs may be associated both to efficient or inefficient DMUs.

Zero inputs: Fried *et al.* (2008) also indicated that zero inputs are more problematic in DEA. Because at least one unit with a zero input will always be VRS or CRS efficient irrespective of the levels of its remaining inputs or outputs. Further explained by Kuosmanen (2002), if zero input represents missing data, and we want to ignore the input from the analysis, then the value of the input must be replaced by a sufficiently large positive value (M). This replacement would force the DMU to assign a zero weight to the missing input value. This replacement, therefore, makes the resulting efficiency score to be the same as that obtained when the input is not considered in the analysis at all. According to Fried *et al.* (2008), when zero inputs are associated with management choices, then there needs to be aware that it implies the existence of a restricted reference set for the units with zero inputs. This reference set may be restricted when only one unit has a zero value on a specific input or when more than one DMU has zero values in the same inputs. The latter case implies that these DMUs should only be compared within its technological comparative group and not across all DMUs.

Therefore, before replacement of zero value inputs one should know whether production units having zero levels input(s) operate the same technology as production units with positive values on that input. For instance, to avoid the problem of zero inputs problem, for those farmers who did not apply fertilizer in wheat production in Machakel *wereda*, Ethiopia, Mersha (2004) assigned a small value that approaches zero which is equal to 0.01. On the other hand, Andreu (2008) used production and financial criteria to treat zero inputs used by Kansas farmers. Accordingly, if an input is reported zero and the DMU fails to meet the production criteria and whose total debts to total asset ratios are higher than one were deleted from the sample. However, these criteria cannot be applicable in smallholder farmers’ case where there is no accurate financial recording system.

Despite of those limitations, this study used the data envelopment analysis (DEA). This is due to the fact that besides those drawbacks the approach has its own advantages as well. DEA permits one to assess the relative efficiency of a given producer using series of inputs and outputs. Moreover, the technique does not require an assumption for a specific production function to be used. More importantly, the decision maker does not need prior information about weights of inputs and outputs which reflect the relative importance of the different inputs and outputs. In addition, for each decision making unit (DMU), efficiency is compared to that of an ideal operating unit rather than to the average performance.

2.3.2.2 Determination of Returns to Scale in DEA

In Microeconomics theory of production, for a rational producer or firm one of the principles to achieve its objectives is to operate at most productive scale size. The operation of a rational producer under constant returns to scale (CRS) or second stage of production function enables the producer to minimize costs and maximize outputs/revenues. However, in the short run firms may operate in the zones of increasing returns to scale (IRS) or decreasing returns to scale (DRS) (Kumar and Gulati, 2008). However, in the long run, they will move towards CRS by becoming larger or smaller through input uses to survive in the competitive market. The process might involve changes of a firms' operating strategy in terms of scaling up or scaling down of size. The regulators and policy makers may use this information to determine whether the size of representative firm in the particular industry is appropriate or not (ibid). According to Banker and Thrall (1992) if scale inefficiency appears due to IRS, this would imply that a given DMU has sub-optimal scale size. Therefore, efficiency or average productivity would increase with increasing size of operation. However, if scale inefficiency occurs due to DRS, the implication is that the DMU has supra/above optimal scale size. Thus, efficiency or average productivity would increase with reducing scale of operation. On the other hand CRS is a point of maximum average productivity or inputs are utilized efficiently.

2.3.2.3 Decomposition of Technical Efficiency in DEA

The technical efficiency of a firm is a comparative measure of how well a firm transforms inputs to outputs as compared to its maximum potential level of the output which is represented by its production possibility frontier (Barros and Mascarenhas, 2005). Overall technical efficiency is a measure of technical efficiency under the assumption of constant returns to scale (CRS) (TEcrs). The TEcrs measure helps to determine inefficiency due to the input/output configuration as well as the size of operations. In DEA, TEcrs measure can be decomposed into two mutually exclusive and non-additive components of pure technical efficiency (TEvrs) and scale efficiency (SE) (Kumar and Gulati, 2008). In Kumar and Gulati (2008) it is also mentioned that this decomposition allows an insight into the source of inefficiencies. The TEvrs measure is obtained by estimating the efficient frontier under the assumption of VRS. It purely reflects the managerial performance of the DMU to organize the inputs in the production process hence called pure technical efficiency. The ratio of TEcrs to TEvrs provides scale efficiency (SE). The measure of SE provides the ability of the management to choose the optimum size of resources or inputs. Therefore, the concept of technical efficiency in terms of its components is important for better understanding of the production processes by the smallholder farmer. It enables one to find out whether the source of technical inefficiency in the crops production is due to poor managerial ability or inappropriate utilization/exploitation of resources. On the other hand, it gives evidence on the seriousness of over utilization of natural resources or use of above recommended rate of inputs in crops production. In this regard, the use of DEA is preferred regarding the decomposition of technical efficiency. First, it allows the estimation of overall technical efficiency and decomposes it into pure technical efficiency and scale efficiency. Furthermore, it also identifies the farms that are operating under different returns to scale.

2.3.2.4 Variable Selection and Model Specification in DEA

Although model misspecification is potentially a serious problem in DEA, it has received very little attention in the literature. Tests for model misspecification generally and for correct input and output variable selection in particular in DEA has been an ongoing controversial debate as there are no diagnostic checks which are in prevalent use in econometrics (Galagedera and Silvapulle, 2000). On the other hand, in computing the efficiency scores, the most challenging task that a researcher encounters is to select the relevant input and output variables for DEA efficiency estimation process.

However, DEA does not require a specific priori structural specification for the production frontier. It uses a linear programming method which avoids the danger of misspecification of the production function which is a common problem in econometric models. But, the sensitivity of DEA efficiency estimates to input variable selection and model specification has been another concern for practitioners (Galagedera and Silvapulle, 2000).

Pedraja-Chaparro *et al.* (1999) have shown that DEA relative efficiency is influenced by the distribution of true efficiencies, the sample size, the number of inputs and outputs included in the analysis and the degree of correlation between inputs. Galagedera and Silvapulle (2000) have found that efficiency results vary considerably with various input-output variable combinations.

Recognizing this shortcoming in DEA, some researchers (such as Galagedera and Silvapulle, 2000; Ruggiero, 1998 and Tran *et al.* 2008 among others) have conducted studies to find out the sources of model misspecification in DEA. According to Galagedera and Silvapulle (2000), the major causes of model misspecification in DEA are known to be omission of relevant variables; inclusion of irrelevant variables; incorrect assumption on returns to scale (RS**)** and the sample size. When important variables are omitted the results may be far from reality. On the other hand, increasing the number of variables decreases the ability of the model to differentiate individual production units in terms of efficiency. In the contrary, Ruggiero (1998) has investigated the impact of inclusion of inappropriate variables on technical efficiency measurement in a variable returns to scale DEA model with multiple outputs. The author documented that DEA performs well in the presence of additional inputs even though they are production irrelevant. However, the author underestimates that inclusion of inappropriate/ irrelevant variables leads to misrepresentation of the reality hence wrong conclusions. Smith (1997) also examined the implication for DEA efficiency scores of using a mis-specified single output constant return to scale model. The author investigated the robustness of DEA results to omission and inclusion of only a single input. It was concluded that the dangers of misspecification are most serious when simple models are used and sample sizes are small. In the current study, therefore, to reduce limitations of the DEA model, those inputs which are commonly used and fundamentally important in the smallholder agricultural production were included.

There are also rule of thumbs regarding the appropriate sample size. Cooper *et al.* (2007) provides two such rules that can be jointly expressed as: $n \geq \max (m \times s; 3(m + s))$; where n refers to number of DMUs (sample size), *m* for number of inputs and *s* stands for number of outputs. The first rule of thumb states that sample size should be greater than or equal to product of the number of inputs and outputs. On the other hand, the second rule states that sample size should be at least three times the sum of number of input and output variables. If the number of DMUs is less than the combined number of inputs and outputs, a large portion of the DMUs will be identified as efficient. Moreover, efficiency discrimination among DMUs is questionable due to an inadequate number of degrees of freedom (due to small sample size). The problem of degrees of freedom is significant in DEA because of its orientation to relative efficiency (ibid). As result, the rule of thumb for determination of sample size in smallholder agriculture may not be effective where there are many producers and types of inputs and outputs for a specific crop are almost common and fundamental. Moreover, the problem of misspecification is most serious when sample sizes are small.

Moreover, existence of outliers in the data is the main sources of DEA specification problems that can seriously affect efficiency scores. According to Tran *et al.* (2008) outliers can be defined as those observations with large influence on the construction of the efficiency frontier. The authors further explained that these impacts of outliers can be construed either in terms of the relative frequency (counts) (C_j) with which an observation appears on the frontier. Alternatively, cumulative weight (sum) (S_j) an observation carries when the frontier is being built can be applied to construct the impacts. Since outliers refer to observations which are on the efficient frontier the DEA model yields nonzero values for (C_j) and (S_j) for efficient firms. In other words, all inefficient firms will have zero values of lambda-count and lambda-sum. The author further indicates that based on the values of C_j and S_j, those observations in the dataset that exert an especially strong influence on the construction of the efficient frontier are potentially outliers. After identifying an observation with a relatively high frequency one can investigate further and consider dropping the observation from the sample. Doing so, results in a new dataset with a sample size of *j* minus 1.Then, in an iterative fashion, one can continue to drop those observations with high values of lambda-count or lambda-sum after each DEA run. The process stops once a desired degree of convergence via visual interpretation of the data in the observed weights has been reached (ibid).

2.4 Determinants of Efficiency

Efficiency estimation without clearly identifying important socio economic and demographic, institutional and policy variables, has limited importance for policy and management purposes. Thus, in this study, identification and analysis of the underlying factors of inefficiency was given priority. Previous empirical studies on agricultural resource use efficiency by Okoye *et al.* (2007), Javed (2009), Alemdar and Ören (2006) and Nyagaka *et al.* (2010) among others were reviewed for better information regarding the selection of determinants for analyses.

In an empirical study by Okoye *et al.* (2007) to determine economic efficiency in small-holder cocoyam farmers in Anambra state, Nigeria, the determinants of economic efficiency were modeled in terms of socio-economic variables of the farmers and other farmer related factors. The study found that whereas age, level of education and farm size to be negatively and significantly related to economic efficiency; farmer's farming experience and fertilizer use were significantly and positively related to economic efficiency.

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 of farms in cotton-wheat system.

Alemdar and Ören (2006) identified the determinants of technical efficiency of wheat farming in southeastern Anatolina, Turkey. The authors used DEA technique to estimate the level of technical efficiency scores and Tobit regression model to determine source of efficiency. The result showed that there is considerable scope for cost reduction in the region. They also found that land fragmentation was the main determinant of technical inefficiency.

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 or club.

Krasachat (2009) measured and investigated factors affecting technical inefficiency of white shrimp farms in Thailand. The DEA approach to estimate technical efficiency scores and a Tobit regression model to determine factors that affect farm efficiency were employed. The author found that the producers who experienced in tiger prawn production are likely to achieve higher levels of overall technical and scale efficiencies. Moreover, the difference in producers' participation in farm management training has led to higher level of scale efficiency in shrimp production. The author also established that the producers' education level has a positive and significant impacts on the overall technical, pure technical and scale efficiencies in Thai shrimp production in Thailand.

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

Nyagaka *et al.* (2010) also 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 indices. Results showed that resource use is subject to decreasing returns to scale. The authors have also found that education, access to extension, access to credit and membership in farmers' association and innovations positively and significantly influence technical efficiency of smallholder potato producers in the district.

Generally, based on the review, factors that have been identified to influence (in)-efficiency in crop production were categorized as farmer characteristics, farm characteristics, policy and Institutional factors and environmental factors. However, even such identification of variables cannot be exhaustive as there are many factors which can potentially affect resource use efficiency in agriculture.

2.5 Review of Empirical Studies on Efficiency from Ethiopia

There is lack of empirical work in Ethiopia on economic efficiency of multiple crops production in the most populated areas and where land is highly fragmented such as the central highlands of Ethiopia. Most of the previous studies (for instance Admassie and Heidhues (1996), Tesfay *et al.* (2005) and Kassie and Holden (2007)) confined in either the estimation of technical efficiency; focused on land renting and sharecropping efficiency; or considered single crop.

Admassie and Heidhues (1996), in their study on the technical efficiency of small-scale farmers in the central highlands of Ethiopia using stochastic frontier analysis, it was established that agricultural production is affected by a host of factors. Although, they did not mention factors that affect technical efficiency other than giving emphasis on the problem of draft power, effect of several demographic, socio-economic and institutional factors on the efficiency of crop production should not be overlooked in the efficiency analysis.

Khairo and Battese (2004), examined technical inefficiencies of maize farmers within and outside the new agricultural extension program in the Harari Region of Ethiopia. Stochastic frontier of production functions were estimated for sample maize farmers within and outside the new agricultural extension program to study technical inefficiencies and identify some of the factors contributing for the variation in productivity. The study found that the average technical efficiencies were 73 percent and factors such as agricultural extension, formal education and off-farm incomes were important factors affecting maize farmers' inefficiencies within the program. However, important socio-economic and institutional factors such as location of farm, proximity to market, participation in community activities and family size were not included in the analysis. Moreover, efficiency estimation may not be consistent as farmers produce series of outputs besides maize.

Bogale and Bogale (2005) examined the technical efficiency of farmers in the production of irrigated potato from randomly selected farmers in four districts of Awi zone in North-western Ethiopia. Using stochastic frontier production function, results indicated that the mean level of technical efficiency was found to be 77 percent and 97 percent respectively for modern and traditional schemes. Irrigation experience, commodity rate of production and size of livestock are found to be important variables that determine the level of efficiency. However, important farmer related variables such as age and sex of the household head and important institutional factors such as membership in associations were not considered in the analysis. More importantly, efficiency estimation from a single crop out of series of outputs may not be consistent with the results had multiple crops considered.

In a study undertaken by Tesfay *et al.* (2005) the technical efficiency levels of peasant farmers in Tigray (Northern Ethiopia) were considered and compared between own and shared-in plots. Results indicated that higher level of technical efficiency scores on own than on sharecropped-in plots. Tenants located in villages with good annual average rainfall and good quality plots, also achieved higher efficiency levels. Technical efficiency was found to have a significant and positive association with livestock endowments of the tenant household and the population density of the location. However, the study result does not show the cumulative effect of land contracting on long-term productivity and sustainability of land use.

On the other hand, Kassie and Holden (2007) examined the threats of eviction and kinship as factors triggering technical efficiency in smallholder sharecropping farming systems in Ethiopia. The authors used a linear household fixed effects method to estimate determinants of output value per hectare. The results showed higher land productivity on sharecropped plots than on share tenants´ own plots and on sharecropped plots of non-kin than that of kin tenants. They explained that non-kin sharecroppers were afraid of eviction and therefore wanted to keep the land with them by producing at higher levels and managing the land more intensively. The result also further implies that ownership of plots or tenure system should be considered in identification of sources of resource use efficiency in agriculture. However, the authors did not consider the effect of important farm and farmers characteristics, socioeconomic and institutional factors on efficiency and productivity besides eviction and kinship.

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. Furthermore, the study also indicated that future endeavors should envisage better market and education access and reduced liquidity constraints. However, the study does not explicitly indicate which agro ecology is more technical efficient/productive in which crop production which could have important policy implication. This is due to the fact that variations in crops production across agro ecologies need different skills which lead to differences in efficiency and productivity.

Gebreegziabher *et al.* (2005) studied the production system of peasant farmers in two districts in Tigray region, northern Ethiopia. The authors employed stochastic frontier production function and to simultaneously determine farmer-specific technical efficiency as well as determinants of inefficiency. Their study revealed that land size and oxen ownership are significant contributors for productivity increments, whereas engagement in off-farm activity was found to decrease inefficiency levels significantly. However, the choice of variables considered in the determination of sources of inefficiency was selected largely based on economic arguments. As a result, important demographic (such as family size), farm specific (for example, location of the farm) and institutional variables including access to market and membership) were overlooked.

Haji (2008) also examined the production efficiency and marketing performance of vegetables in the eastern and central parts of Ethiopia. Efficiency estimation and identification of their determinants in mixed-crop and market driven (vegetables) production systems was performed in two districts of eastern Ethiopia. A significant economic inefficiency was observed for both systems, with lower efficiency scores for the market-driven farm production. Results based on the comparison of the two production systems showed that lower economic efficiency scores for the market driven production is attributable to limited access to capital markets, high consumer spending, and large family size.

In general, despite the fact that efficiency of smallholder farmers has been extensively studied in Ethiopia either from technical or economic efficiency perspectives or regardless of area of study and its crop specificity, it is still an important area of great policy concern. This is because smallholder farmers are major constituent of agricultural producers in developing economies. Therefore, estimation of efficiency and identification of underlying determinants for smallholder farmers has a paramount importance for appropriate policy formulation. 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, 95 percent of all grain crops are produced by smallholder farmers.

However, as it is evident from the preceding discussion that most of the empirical works in Ethiopia have focused on a particular agro-ecology, or concentrated on technical efficiency otherwise they analyzed specific crop production efficiency. Stochastic Frontier analysis is frequently used where the problem of functional specification is serious; the assumptions for stochastic nature of inefficiency scores as a random shock distributed homogeneously across firms is unrealistic. Moreover, SFA allows considering only single output among series of outputs of a farmer unless cost-minimization is assumed which makes efficiency estimation inconsistent. Others did not address the issue of in/efficiency determinants or have overlooked important variables in the analysis.

Therefore, this study was aimed at estimating resource use efficiency of smallholder crop producers and determining the underlying factors affecting the existing inefficiencies. The study used data from *teff*, wheat and chickpea producing three districts, namely Minjar -Shenkora, Gimbichu and Lume Ejere in the central highlands of Ethiopia. In doing so, the study attempted to fill the knowledge gap on the current level of efficiency, further production capacity of crops and the underlying factors causing inefficiency particularly in the study areas.

2.6 Theoretical Framework

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

A firm is technically efficient when maximum level of output is attained for a given level of inputs and the range of technology available. Allocative efficiency is attained when the farmer adjusts outputs and inputs levels to reflect relative prices and the production technology. 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). These concepts can be illustrated graphically using a simple example of a two- input (x_1, x_2) and two-output (y_1, y_2) production process (Figure 1).

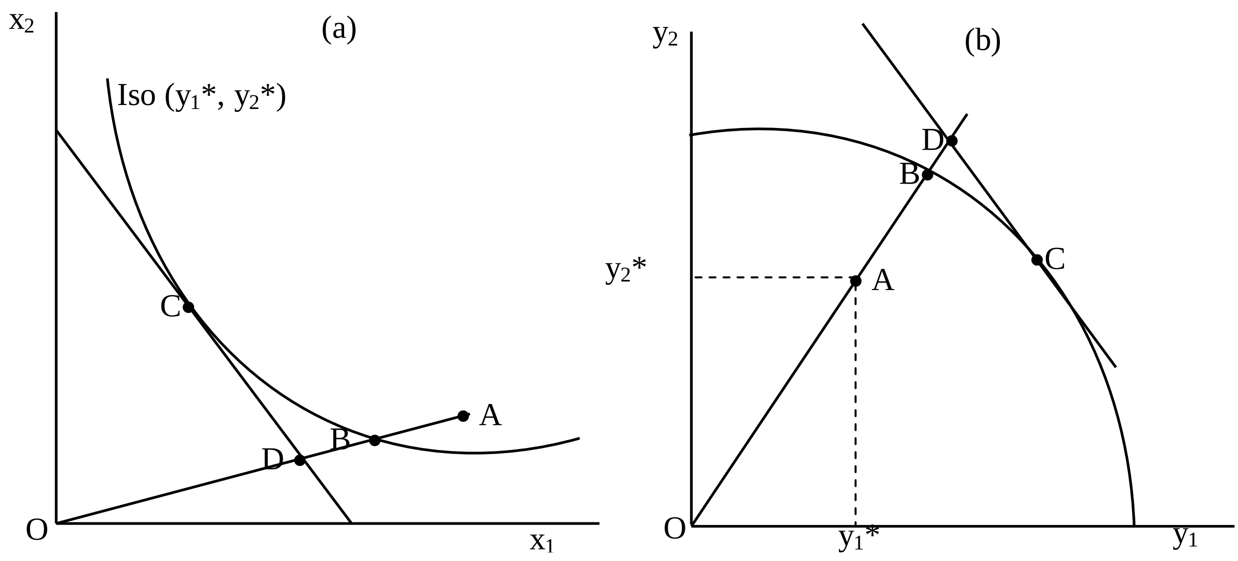

Figure 1: Input (a) and output (b) oriented efficiency measurement

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

In Figure 1 (a), the farm is producing a given level of output (y_1^*, y_2^*) using an input combination defined by point A, which is above the isoquant. The same level of output could have been produced by radially contracting the use of both inputs back to point B, which lies on the isoquant associated with the minimum level of inputs required to produce (y_1^*, y_2^*) this is a technically efficient production point. Point C is also a technically efficient point - meaning that points on isoquant are technically efficient areas of production. The measure of technical efficient of the firm at point A is OB/OA. That is, the farm at point A would reduce both inputs by proportion OB/OA and still produce the same quantity of output(y_1^*, y_2^*). Given relative input prices, isocost line indicate the minimum cost of producing output (y_1^*, y_2^*). The greatest economic efficiency is achieved at point C, at tangency of isocost and isoquant. Since point D is at same level of cost as C, then economic efficiency of farm at A is measured as OD /OA. On the other hand OD/OB represents allocative efficiency or the divergence between minimum cost point and cost incurred at B. Generally, farm at point C is economically efficient, farm at B is technically efficient but not allocative efficient, while farm producing at point A is neither technically nor allocative efficient. Therefore economic efficiency can be decomposed as: OD /OA= OB/OA * OD/OB. Generally. This type of efficiency measurement is called input oriented efficiency measurement (Coelli *et al.*, 2005).

In Figure 1 (b), the type of efficiency measurement is output oriented efficiency measurement (Coelli *et al.*, 2005). In this case the measurement of firm specific technical efficiency is based upon deviations of observed output from the best production or efficient production frontier. If a firm's actual production point lies on the frontier it is perfectly efficient (points B and C). If it lies below the frontier then it is technically inefficient (point A), with the ratio of the actual to potential production defining the level of technical efficiency of the smallholder farmer. Profit maximization requires a firm to produce the maximum output given the level of inputs employed (be technically efficient), use the right mix of inputs in light of the relative price of each input (be input allocative efficient) and produce the right mix of outputs given the set of prices (be output allocative efficient on Point C). However, the term technical efficiency is used to distinguish the technological aspects of production processes from other aspects such as economic efficiency which is of interest to economists. Because economics efficiency involves recourse to information on prices, costs or other value considerations (Cooper *et al*., 2000).

2.7 Conceptual Framework

Figure 2 shows the interaction of various factors that were considered to have a various degrees and directions of impact on the level of economic efficiency in smallholder crops production. Studies, for instance, by Kalirajan and Shand (1988) and Haji (2006) showed that efficiency of production was determined by the host of socio-economic and institutional factors. These factors directly/indirectly affect the quality of management of the farm's operator and, therefore, are believed to have impact on the level of technical and economic inefficiency of farms. According to Bakhsh (2007), a range of factors like distinctiveness of farms, management, physical, institutional and environmental aspects could be the cause of inefficiencies in the production process of the farmers.

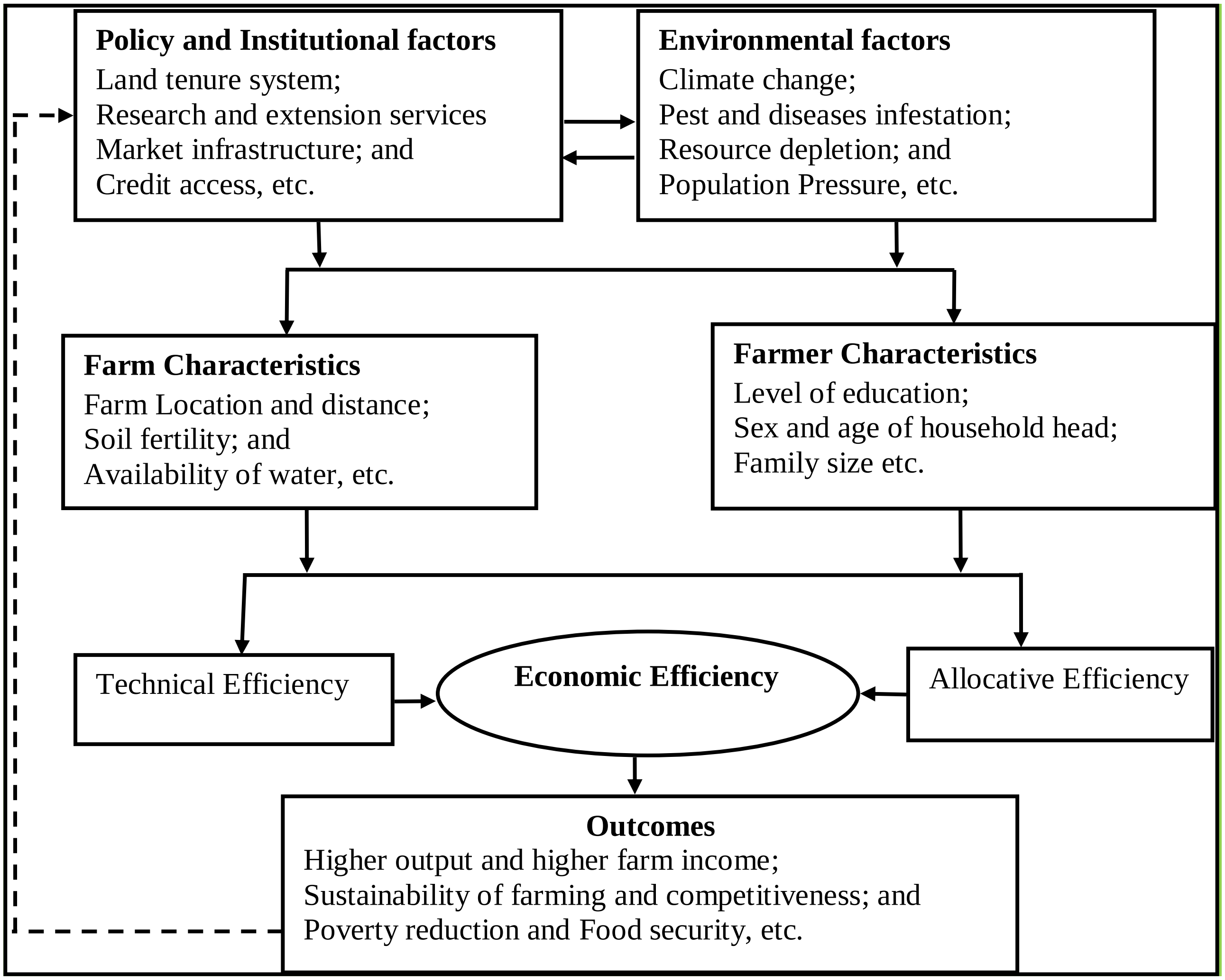

Figure 2: Conceptual framework of Economic Efficiency in crops production

Source: Own conceptualization

2.7.1 Policy and Institutional Factors

Policy and institutional factors such as land tenure system, economic system and market infrastructure, credit and input accesses can have significant effect on the resource use efficiency of crops production. According to Nossal and Gooday (2009) some policy regulations provide a disincentive for producers to be innovative and change practices in response to market developments. They also further indicated that policy reforms encouraging competition and reducing regulatory constraints will provide a stronger basis to enable productivity gains. On the other hand, Tchale (2009) explained that extension and access to markets are important policy and institutional variables that positively influence efficiency. They provide incentive and means to access improved crop technology via improving farmers' liquidity and the affordability of the inputs required for production. Therefore, improvement of efficiency hinges largely on improving the policy and institutional environment. The author also argues that efforts must be made to promote private market development (Tchale, 2009). According to Pinckney (1993 cited in Tchale, 2009) the institutional and policy issues such as markets and other public provisions are just as important as technological factors in improving overall efficiency in the smallholder subsector. Wang *et al.* (1996) explained that reducing market distortions, allowing land use rights to transfer more freely and farmers' access to education can improve both technical and allocative efficiencies. Therefore, policies, programs and institutional arrangements which target access to credit, market infrastructure, access to education and land tenure systems among others are important variables that can substantially affect resource use efficiency and productivity.

2.7.2 Environmental Factors

Environmental factors such as climate change, weather condition, resource depletion, and population pressure can affect resource use efficiency in crops production. According to Nossal and Gooday (2009) climate change, resource depletion and other environmental pressures pose a major threat to productivity growth. Van Passel *et al.* (undated) explained that differences in efficiency between farmers can be explained by environmental characteristics, such as soil quality, vegetation cover, altitude, climate, rainfall and temperature among others. However, Dudu (2006) indicated that there may be a negative interaction between some agricultural practices and the environment. For instance excessive use of pesticides and fertilizers may affect both the environment and productivity of the basic factors of production. According to Ajibefun (2002), in Nigeria, as the population pressure increases, farmers are forced to produce more food. As a result people are being pushed to new agricultural lands and many into marginal lands. Therefore, environmental factors such as climate change, population pressure and resource depletion should be considered to address problems related to resource use efficiency and productivity of farmers.

2.7.3 Farmer Characteristics

Level of producer's education and years of experience influences the producer's management capacity. Quisumbing (1995) mentioned that farmers with more education, more land and farm tools are more likely to adopt new technologies. Moreover, Wang *et al.* (1996) explained that resource endowment and education level of farmers influence their allocative efficiency. In addition, the authors indicated that family size, per capita net income, and family members operating as village leaders are positively related to their production efficiency. Ajibefun (2002) indicated that education level of farmers and farming experience are important determinants of efficiency which can be incorporated into the agricultural policy. Thus, factors related to farmer characteristics are included in the analysis believing that they have effects on efficiency and productivity of the farmer.

2.7.4 Farm Characteristics

Efficiency variations between farms can also be explained by the farm location and environmental characteristics. Farm location is important since farms may operate under different climate or altitude conditions and different soil quality and availability of water. Moreover, farm geographical location which links to environmental characteristics can be one of the factors explaining differences in efficiency (Wang *et al.*, 1996; O'Neill *et al.*, 2001; Rezitis *et al.*, 2002). Farm related variables are important because in most farming systems in sub-Saharan Africa there are significant variations in terms of plot-level biophysical and soil chemical characteristics (Tchale, 2009).

2.7.5 Feedback Effect

The final element of the framework is the feedback effect of the interaction of various external (policy, institutional and environmental factors) and internal (farmer and farm characteristics) variables for further reforms. It indicates whether the interventions or changed practices have impacts in the society. According to Bruch *et al.* (2009) the feedback effects of targeted programs can be positive or negative; and such effects tend to be more positive when a policy's authority structure reflects democratic rather than paternalist principles. Moreover, Asselin (2003) indicated that the country circumstances (socio-economic and scale and complexity of the policy adjustment) will ultimately determine the strength of feedback effects for policy reform. Accordingly, the broken line in the figure shows such conditions in the economic and political system and effectiveness of research and extension system to respond for the feedback from the smallholder farmer.

CHAPTER THREE

METHODOLOGY

3.1 Description of the Study Areas

Ethiopia has the largest highland areas (defined as areas above 1500 meters above sea level) in the African continent, constituting about half of the country. The highlands are home to about 90% of the total population (ILCA, 1983). The highlands also contain over 95 percent of the regularly cropped areas and around two-thirds of the livestock. Moreover, it is estimated that 90 percent of the country's economic activity and gross domestic product are generated from these highlands (Constable, 1985 cited in Bishaw, 1993). The study areas were Minjar-Shenkora, Gimbichu and Lume-Ejere districts. They are found in the Shewa region in the central highlands of the country and are located north east of Debre Zeit, which is 50 km south east of the capital, Addis Ababa. Debre Zeit Agricultural Research Centre (DZARC) is also located in the area and is a big asset to the districts in terms of information on quality seed, agronomic practices, marketing, storage, introducing new crop varieties and other relevant information.

The study areas have an aggregate total population of 345,177 persons of which 135746, 92930 and 116501 persons are living in Minjar-Shenkora, Gimbichu and Lume-Ejere districts, respectively. The districts have also total of 52,929 farm households and 95 Peasant associations. The total area size of all the three districts is about 379,754.25 ha of which 138,459.82 ha (36.46 percent) is arable land. On average, a household in the study areas owns about 2.62 hectares of land which is relatively more than the average land holding in the highlands that ranges from 0.5 to 2.5 ha and 1.2 ha in the rural Ethiopia. At district level, the average household land holding is about 1.96, 3.23 and 3.06 ha of land per farm household for Minjar Shenkora, Gimbichu and Lume Ejere districts, respectively. Despite its impact on environment and distribution of arable land the larger population would have potential demand for agricultural and non-agricultural produces in the study areas.

Gimbichu district is characterized by moderate to cool moist, mid to high altitude (900 meters to 2700 meters above sea level). It has also eutric vertisol soil type. On the other hand, Lume Ejere district is regarded as an area with tepid to cool sub humid, high altitude (1604 meters to 2364 meters above sea level). Similarly, it has a eutric vertisol soil type. Moreover, Minjar-shenkora district is characterized by tepid to cool sub humid, with altitude raging from 1040 meters to 2380 meters above sea level. The soil type in this district is categorized as eutric vertisol with its clay texture. The districts are getting annual rainfalls of 800mm-1000mm, 800mm-1000mm and 500mm-1200mm for Minjar-Shenkora, Gimbichu and Lume Ejere districts, respectively. The soil types, altitude and the available sufficient rainfall help the study areas to be one of the major crop producer regions in Ethiopia.

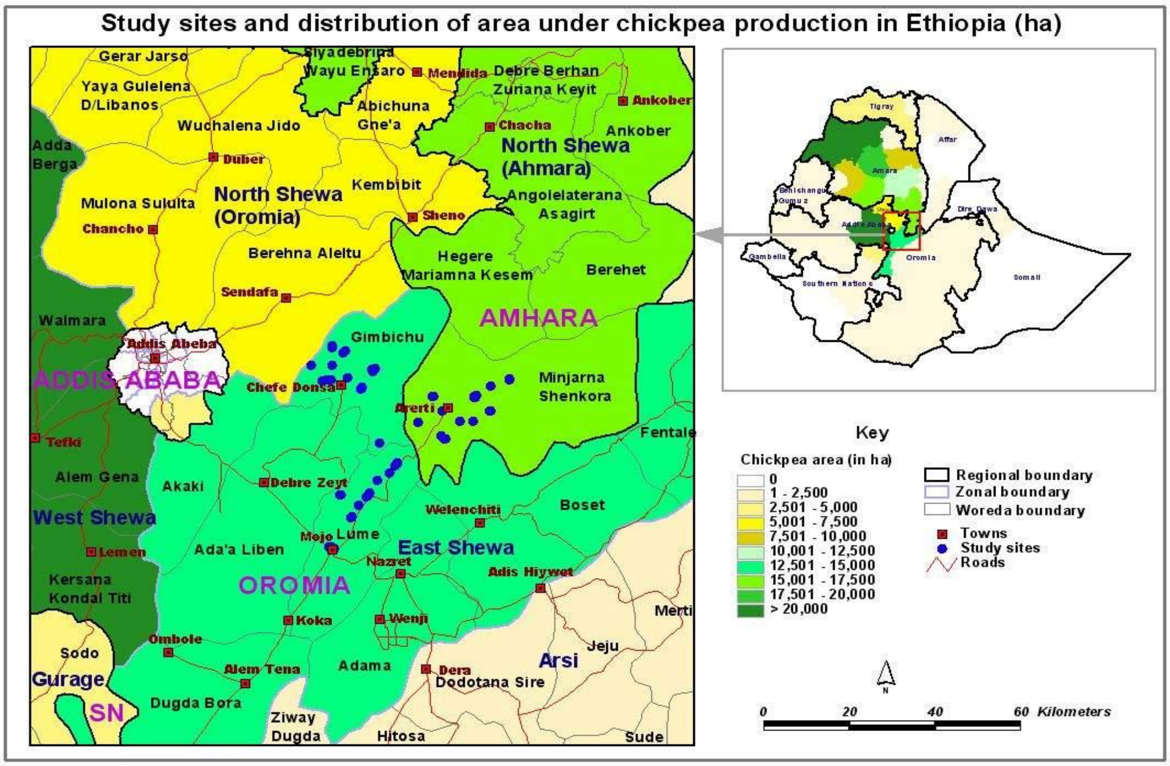

Figure 3: Map of the study areas

Source: The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), 2008

The agricultural production system in the study areas is mixed crop-livestock (traditional) agricultural system whereby smallholder farmer practices crops and livestock production under the same management. The major crops grown in include *teff* (*Eragrostis tef*), wheat, barley, horse beans, maize, sorghum, chickpeas, lentils, banana and coffee. These crops are produced both for source of cash and for household consumption. Cattle, goats, sheep, equines and poultry are also important tame animals kept by the smallholder farmers integrated with crops production. Thus, both crops and livestock contribute their share to the farmers' agricultural income. *Teff,* Wheat and chickpea (considered in this study) are the major annual crops grown in the districts.

3.2 Methods of Data collection and Data Sources

3.2.1 Sampling Techniques

The data used for this study originates from a baseline survey conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Ethiopian Institute of Agricultural Research (EIAR).

A multi-stage sampling procedure was used to select districts, *kebeles*[1] and farm households. In the first stage, three districts namely Minjar-Shenkora, Gimbichu and Lume-Ejere were selected purposively based on the intensity of crops production, agro-ecology and accessibility. In the second stage, eight *kebeles* from each of Gimbichu and Lume-Ejere districts and ten *kebeles* from Minjar-Shenkora district randomly selected. In the third stage a representative sample of 700 households (of 149, 300 and 251 farm households from Gimbichu, Lume-Ejere and Minjar-Shenkora districts, respectively) were selected.

3.2.2. Data Collection

A formal survey instrument was prepared and data were collected by trained enumerators from the households using structured interview schedule. The survey collected valuable information on several factors including household composition and characteristics, land and non-land farm assets, household membership in different rural institutions, area planted, costs of production, output data for different crop types, indicators of access to infrastructure and household market participation.

[1] *It is usually named peasant association and is the lowest administrative unit in the country.*

3.3 Data Analyses

3.3.1 Descriptive Statistics

The relevant data were analyzed using descriptive statistics such as mean, frequency, standard deviation, graphs and figures. These descriptive statistical techniques helped to describe demographic, socio economic and institutional characteristics of smallholder crops producers. Input uses and outputs of production processes and efficiency distributions among sample farmers were also presented using descriptive statistics.

3.3.2 Mathematical and Econometric Analyses

3.3.2.1 Mathematical Specification of the DEA Approach

DEA is a non-parametric technique used in the estimation of production functions and has been used extensively to estimate measures of technical efficiency in a range of industries (Cooper *et al.*, 2000). The method was used to estimate the relative technical and economic hence alloactive efficiency of smallholder farmers.

Estimation of Technical Efficiency

Technical efficiency is the efficiency in converting inputs to outputs. It exists when it is possible to produce more outputs with the fixed inputs used (called output- orientated) or to produce the given level of outputs with fewer inputs (called input-orientated). In other words, it can be stated as the ratio of sum of weighted outputs to sum of weighted inputs and can be shown as following formula (Cooper *et al.*, 2004):

$$TE_j = \frac{U_1Y_{1j} + U_2Y_{2j} + ... + U_kY_{kj}}{V_1X_{1j} + V_2X_{2j} + ... + V_mX_{mj}} = \frac{\sum_{r=1}^{k} UrY_{rj}}{\sum_{s=1}^{m} V_sX_{sj}} \quad (1)$$

where X_i and Y_i are inputs used and outputs produced; V_i and U_i are input and output weights, respectively; s is number of inputs ($s = 1,2,. . .,m$), r is number of outputs ($r = 1,2,..,k$) and j represents j^{th} DMUs ($j = 1,2,. . .,n$).

Therefore, taking the output orientated approach the producer maximizes the output level given fixed inputs. Mathematically, it is written as:

$$\text{Max.:} \quad \frac{\sum_{r=1}^{k} UrY_{ri}}{\sum_{s=1}^{m} V_s X_{si}} \tag{2}$$

S.t.:

$$\frac{\sum_{r=1}^{k} UrY_{ri}}{\sum_{s=1}^{m} V_s X_{si}} \le 1 \quad , \forall_i \;\; U_r, V_s \ge 0, \tag{3}$$

where r is number of outputs produced ($r=1,2,3,\ldots k$), s is number of inputs utilized ($s=1,2,3,\ldots m,$), i is the DMU considered ($i=1,2,3,\ldots n$), X_{si} is amount of input s utilized by DMU i, Y_{ri} is amount of output r produced by DMU i, U_r is weight given to output r, and V_s is weight given to input s. Weights reflect the relative importance of inputs and outputs for efficient firms and weights assigned to peers for inefficient firms. They are used to linearly aggregated inputs and outputs. They will be calculated by solving the linear programming problem.

In order to solve equations (2 and 3), the following equation developed by Charnes, Cooper and Rhodes (CCR) (1978) was used.

$$Max: \theta = U_1Y_1 + U_2Y_2 + \ldots + UrY_{ri} \tag{4}$$

S.t.:

$$V_1Y_{1i} + V_2Y_{2i} + \ldots + V_sY_{si} = 1 \tag{5}$$

$$U_1Y_{1j} + U_2Y_{2j} + \ldots + U_rY_{rj} \le V_1Y_{1j} + V_2Y_{2j} + \ldots + V_sY_{sij} \tag{6}$$

$$U_1, U_{2.}, \ldots, U_r \ge 0 \tag{7}$$

$$V_1, V_{2.}, \ldots, V_s \ge 0, \text{and } (i \text{ and } j = 1, 2, \ldots, k) \tag{8}$$

where θ is the technical efficiency and i represents i^{th} DMU. The CCR model assumes Constant Returns to Scale (CRS). According to Coelli *et al.* (2005), there will always be financial limitations or imperfect competitive markets where increased amounts of inputs do not proportionally increase the amount of outputs obtained. In order to account for this effect, the DEA model for Variable Returns to Scale (VRS) was developed by Banker, Charnes and Cooper (BCC) (1984) approach (Banker *et al.*, 1984). The VRS model allows an increase in input values to result in a non-proportional increase of output levels. The VRS surface envelops the population by connecting the outermost DMUs, including the one approached by the CRS surface. Hence the BCC model envelops more data and efficiency scores are bigger than or equal to scores of CCR.

To estimate technical efficiency the BCC approach for output orientated can be written as:

$$\mathrm{Max}_{\phi\lambda} \ \phi, \tag{9}$$

S.t.:

$$x_i - X\lambda \geq 0 \tag{10}$$

$$-\phi y_i + Y\lambda \geq 0 \tag{11}$$

$$N1'\lambda = 1 \tag{12}$$

$$\lambda \geq 0, \tag{13}$$

In the restriction $N1'\lambda = 1$, $N1'$ is convexity constraint which is an N×1 vector of ones and λ is an N×1 vector of weights which defines the linear combination of the peers of the i^{th} farm. $1 \leq \phi \leq \infty$ and ϕ-1 is the proportional increase in outputs that could be achieved by the i^{th} DMU with the input quantities held constant. Note that $1/\phi$ defines a TE score which varies between zero and one. If ϕ =1 then the farm is on the frontier and is technically efficient and if ϕ< 1 the farm lies below the frontier and is technically inefficient.

Estimation of Economic Efficiency

Using the BCC approach, in order to investigate the economic efficiency or cost efficiency, the input orientated cost minimization DEA is specified as:

$$\text{Min } \lambda, x_i^* \; W_i^{'} X_i^* \qquad (14)$$

S.t.:

$$-y_i + Y\lambda \geq 0, \qquad (15)$$

$$X_i^* - X\lambda \geq 0 \qquad (16)$$

$$N1'\lambda = 1 \qquad (17)$$

$$\lambda \geq 0 \qquad (18)$$

where, $W_i^{'}$ is a transpose vector of input prices for the i^{th} DMU and X_i^* is the cost-minimizing vector of input quantities for the i^{th} farm given the input prices. Economic efficiency is the ratio of potential minimum cost of production $W_i^{'} X_i^*$ and the actual cost of production $W_i^{'} X$ as:

$$EE = \frac{W_i^{'} X_i^*}{W_i^{'} X_i} \qquad (19)$$

Allocative efficiency can be estimated as the ratio of economic efficiency and technical efficiency as $AE = {EE}/{TE}$. It is also important to note that this procedure includes any slacks into the allocative efficiency measure, reflecting an inappropriate input mix (Ferrier and Lovell 1990). Efficiency scores in this study were estimated using DEAP Version 2.1 (Coelli, 1996).

Variables for Data Envelopment Analysis

In this study, the output variables were outputs of Chickpea, *Teff* and wheat whereas input data were total area of land in hectare ploughed under the three crops, total labor (both family and hired ones) used for the production activities of the three crops, total amount if DAP and urea fertilizers used, total amount of field chemicals applied and amount of seed used for each crops. The costs associated for each input were also included in the DEA approach (Table 1).

Table 1: Description of Variables for Data Envelopment Analysis

Variables	Description	Unit of Measurement
Output variables		
$\mathbf{Y_1}$	*Teff*	Kilograms
$\mathbf{Y_2}$	Wheat	Kilograms
$\mathbf{Y_3}$	Chickpea	Kilograms
Input Variables		
$\mathbf{X_1}$	Total Land cultivated for the three crops	Hectare
$\mathbf{X_2}$	Total labor (Family and Hired) Utilized	Man days
$\mathbf{X_3}$	Amount of Agro chemicals applied	Kilograms
$\mathbf{X_4}$	Amount of Urea used	Kilograms
$\mathbf{X_5}$	Amount of DAP used	Kilograms
$\mathbf{X_6}$	Amount of Chickpea seed used	Kilograms
$\mathbf{X_7}$	Amount of *Teff* seed used	Kilograms
$\mathbf{X_8}$	Amount of Wheat seed used	Kilograms
Input Cost Variables		
$\mathbf{C_1}$	Land rent (cost of land)	Birr per hectare
$\mathbf{C_2}$	Total wage for Labor	Birr per Man/day
$\mathbf{C_3}$	Cost of Agrochemicals and pesticides	Birr per bottle
$\mathbf{C_4}$	Cost of Urea used	Birr per 100kg
$\mathbf{C_5}$	Cost of DAP used	Birr per 100kg
$\mathbf{C_6}$	Cost of Chickpea seed used	Birr per kg
$\mathbf{C_7}$	Cost of *Teff* seed used	Birr per kg
$\mathbf{C_8}$	Cost of Wheat seed used	Birr per kg

3.3.2.2 Econometric Specification of Tobit Regression Model

In order to address objective 3 various socio-economic and institutional variables were regressed on inefficiency estimates of farms using a two- limit Tobit regression model. The Tobit model was adopted because the efficiency scores lie within a double bounded range of 0 to 1 or proportions that is censored in both tails.

Following Upadhyaya *et al.* (1993) and Amemiya (1985) the two-limit Tobit regression model of the following form was estimated:

$$U_i^* = \beta_0 + \sum_{j=1}^{k} \beta_j Z_{ij} + \mu_i, \qquad (20)$$

$$U_i = 1, \quad if\ U_i^* \geq 1 \qquad (21)$$

$$U_i = U_i^*, \quad if\ 0 < U_i^* < 1 \qquad (22)$$

$$U_i = 0, \quad if\ U_i^* \leq 0 \qquad (23)$$

where: i refers to the i^{th} farm in the sample, U_i is inefficiency scores representing technical and economic inefficiency of the i^{th} farm. U_i^* is the latent variable, β_j are parameters of interest to be estimated and μ_i is random error term that is independently and normally distributed with mean zero and common variance of δ^2 (μ_i ~NI $(0, \delta^2)$). Z_{ij} are socio economic, institutional and demographic variables which are expected to affect inefficiency scores.

Description of Tobit Regression Model Variables

Table 2 presents the hypothesized effects of different farmer and farm, and socio-economic and institutional related variables on inefficiency. In the model the dependent variables were technical and economic inefficiency score computed as one minus the efficiency scores for the DMUs considered.

Table 2: Hypothesized Effects of Explanatory Variables on Inefficiency Scores

Two - limit Tobit Regression Model Variables (dependant Variable- Inefficiency scores)			
Explanatory Variables	Description of Variables	Unit of Measurement	Hypothesized Sign
farmexpr	Experience of growing chickpea since formed a family	Years	-
familysize	Family Size	number	-
membership	Household Membership to Farmers' Associations, Cooperatives and groups (Dummy)	Yes =1 , otherwise =0	-
hheadeduc	Education Level of household head	years	-
creditacc	Access to credit service at market interest rate (Dummy)	Yes=1 , otherwise=0	-
contextag	Number of contacts with extension agents	Days per year	-
age	Age of the household head	years	-
gender	Sex of the household head (Dummy)	Female =0, Male =1	-/+
wlkdsmnm	Walking distance to the nearest main market	kilometers	+
rolecommu	Leadership (Role) of the household head in the community	Yes=1, otherwise =0	-/+
plotdist	Average plot distance from residence	kilometers	+
cultrany	Total Own cultivated land during long rainy season	hectare	+

Marginal Effects for Two-Limit Tobit Regression Model

The Tobit regression model coefficients do not directly give the marginal effects of the associated independent variables on the dependent variable. But their signs show the direction of change in the dependent variable as the respective explanatory variables change (Amemiya, 1984; Goodwin, 1992; Maddala, 1985).

In Sigelman and Zeng (1999) it is pointed out that in the Tobit model there are there expected values each for latent (y^*), uncensored observed ($y/y > 0$) and both censored and uncensored observed (y) values of the dependent variable. However, as Greene (2003) notes, there is no consensus on which value to report and much will depend on the purpose of the analysis. The author suggests that if the data is always censored, then focusing on the latent variable is not particularly useful. Wooldridge (2002) also argues that if one is employing a corner solution model then the interest probably is not in the latent (unobserved) variable. If the interested is in the effects of explanatory variables that may or may not be censored then probably *E(y)* is important. But if the interested is in just the uncensored observations, the focus probably lies on $E(y/y > 0)$. Greene (2003) seems to support the idea that *E(y)* as the most useful but also suggests that the intended particular purpose of the study must be taken in to consideration.

Accordingly, the Tobit Regression model results can provide three possible marginal effects for the corresponding expected values mentioned above.

1. Marginal effect on the latent dependent variable, y^*: $\frac{\partial E(y^*/x)}{\partial x_k} = \beta_x$

   Thus, the reported Tobit coefficients indicate how a one unit change in an independent variable x_k alters the latent (unobserved) dependent variable.

2. Marginal effect on the expected value for y for uncensored observations:

$$\frac{\partial E(y_i / y > 0)}{\partial X_k} = \beta_k\left(1 - \lambda(\alpha)\left[\frac{x_i\beta}{\sigma} + \lambda(\alpha)\right]\right) \text{ Where } \lambda(\alpha) = \left[\frac{\phi\frac{x_i\beta}{\sigma}}{\Phi\frac{x_i\beta}{\sigma}}\right]$$

   This indicates how a one unit change in an independent variable x_k affects uncensored observations.

3. Marginal effect of an explanatory variable on the expected value for y (dependent variable) (both censored and uncensored) *E(y):* $\frac{\partial E(y/x)}{\partial x_k} = \Phi\left(\frac{x_i\beta}{\sigma}\right)\beta_x$

where, X_i are explanatory variables; $\delta = \frac{\beta_i X_i}{\sigma}$ is the Z-score for the area under normal curve; β_k is a vector of Tobit maximum likelihood estimates; σ is the standard error of the error term, ϕ

and Φ are probability density and cumulative density functions of the standard normal distribution, respectively. This is called McDonald - Moffitt's decomposition. It allows us to see that a change in x_k affects the conditional mean of y^* in the positive part of the distribution and it affects the probability that the observation will fall in that part of the distribution (McDonald and Moffitt, 1980; Long, 1997). The expression $\Phi\left(\frac{x_i \hat{\beta}}{\hat{\sigma}}\right)$ which is called the Scale Factor for effects is simply the estimated probability of observing an uncensored observation at the values of x_i or it is the sample proportion of non-limit observations in the total observation.

The maximum likelihood estimation consists of the product of expressions for the probability of obtaining each observation. For each non-limit observation this expression is just the height of the appropriate density function representing the probability of getting that particular observation (Peter, 1998). However, which of these marginal effects should be reported will depend on the purpose of the study. Wooldridge (2002) recommends reporting both the marginal effects on *E(y)* (both censored and uncensored) and $E(y/y > 0)$ (uncensored).

In this study, the Marginal effect of explanatory variables represented as $\left(\partial y / \partial x\right)$ on the expected value for inefficiency scores (dependent variable) (both censored and uncensored was considered.

CHAPTER 4

RESULTS AND DISCUSSIONS

This chapter presents the results and discussion part of the study. The first section presents results of the descriptive statistics. The second section deals with efficiency results from Data Envelopment Analysis (DEA). Finally, the two- limit Tobit regression model results of factors affecting resource use efficiency of will be discussed in section three.

4.1 Descriptive Statistics

The descriptive statistics presented in this section is comprised of various sub section. The discussion is categorized as demographic and socio economic characteristics; institutional characteristics; rate of input use (input per unit of land) and crop yields (output per unit of land) and description of variables used in DEA.

4.1.1 Demographic and Socio economic characteristics

Table 3 presents selected demographic and socio economic characteristics of sample households. In the table, it is shown that in the study areas the average family size is 6.4 persons per household. The result implies that the mean family size in the study areas is relatively higher than the national average agricultural household size which is about 5.2 persons per household. It is believed that too large family size is a greater challenge for family resource distribution than an asset as source of cheap labor in the agricultural production. This ultimately reduces agricultural productivity and causes rural-urban migration. Moreover, larger family size contributes for population expansion and ultimately encroachment of agricultural practice to the marginal areas that causes further environmental degradation.

The average age of sample household heads was 47.2 years with standard deviation of 12.54. On the other hand, 7.14 percent of households are female-headed. In Ethiopia, the ratio of national average female-headed agricultural households is about 17.6 percent that makes the study areas to have relatively lower proportion compared to the national average. It is understood that female-headed households face greater challenges in the agricultural production and marketing compared with their male-headed counterparts. This is due to the fact that female household heads in the rural Ethiopia hold various tasks including collecting of fire wood from the field, fetching water from the far distant rivers, childrearing and household management obligations. In addition, they have farm management tasks that increase the burden. Such multiple tasks combined with less resource accesses and ownership would likely lead to more frequent and perhaps severe economic and social shocks particularly poverty and food insecurity.

Moreover, on average, household heads have 1.74 years of education level which is the lowest at any given standard. This might have a potential hindrance effect on effective technology transfer and adoption in the study areas. In addition, access to education which is measured by the overall adult literacy rate is about 56.15 percent which is relatively higher than the national average of 36 percent but lower than even most sub-Saharan African countries.

Table 3: Summary of demographic and socioeconomic Characteristics (N=700)

Characteristic	Unit	Mean	Standard Deviation
Family Size	Number of Persons	6.4	2.3
Age of the Household head	Years	47.2	12.54
Education level of Household Heads	years	1.74	2.69
Dummy Variable	Response	Frequency	Percent
Sex of Household heads	Male	650	92.86
	Female	50	7.14

Source: Survey data, 2008

The dependency ratio, 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) was about 0.85. This indicates that for every 100 active working persons, there are 85 persons who are not actively working in the study areas. However, this figure is about 0.97 at national level. As a result, the study areas have comparatively lower level of dependent people compared to the national average that relatively eases the burden on the productive labor force.

The average land holding of the farmers was about 2.24 hectares while on average 2.08 and 0.16 hectares of own land were cultivated and left fallowed, respectively. The result implies that farmers in the study areas have relatively larger land size compared to that of the national average of farmers in Ethiopian which is 1.2 ha and of which 55.13 percent of the farmers holding less than 1.0 ha (Gebeyehu, 2010). Furthermore, about 59.57 percent of farmers did not fallow their land in the previous cropping season. This implies that almost every plot of land is being ploughed every year that might lead to loss of fertility and degradation hence marginality due lack of time for rehabilitation of its fertility (Table 4).

Table 4: Own Land distribution, cultivated and fallowed land of sample households

Land Size (ha)	Own land holders		Own land cultivation		Fallowed Land	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
0	38	5.43	39	5.57	417	59.57
0.01-1.99	277	39.57	304	43.43	281	40.14
2.0-3.99	314	44.85	306	43.71	2	0.28
4.0-5.99	52	7.43	40	5.71	0	0
6.0-7.99	15	2.14	11	1.57	0	0
8.0-9.99	2	0.28	0	0	0	0
>=10	2	0.28	1	0.14	0	0
Mean (ha)	2.24		2.08		0.16	

Source: Survey data, 2008

Figure 4 shows that 44.85 percent of households own land between 2.0 to 3.99 hectares followed by 39.57 percent of households holding land size between 0.01 to 1.99 hectares.

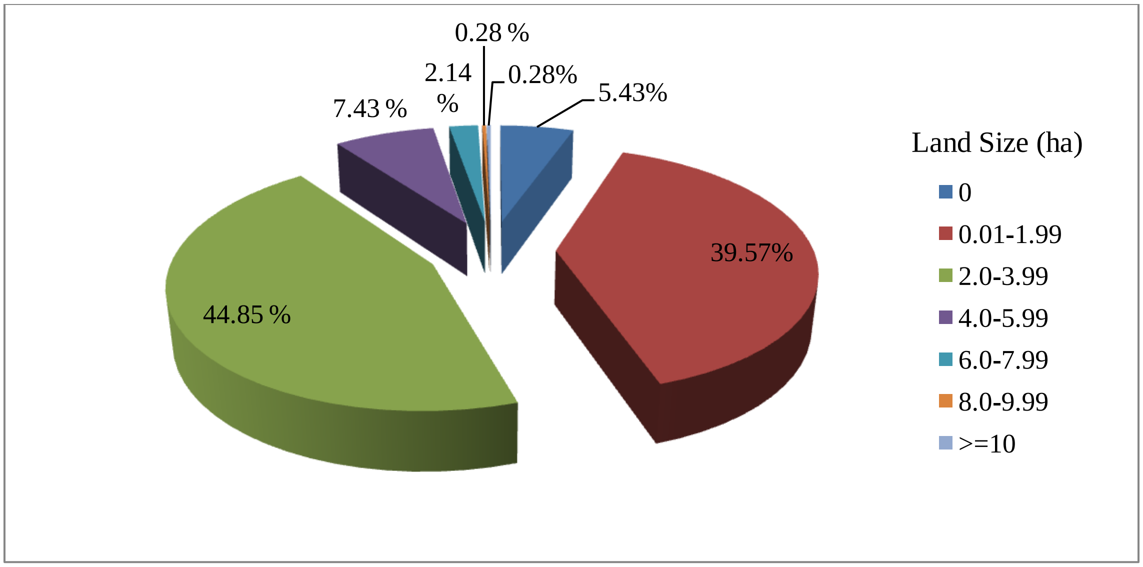

Figure 4: Distribution of Land among Sample households (Percent)
Source: Survey data, 2008

4.1.3 Institutional Characteristics

Table 5 presents the summary statistics of some institutional characteristics of households in aggregate in the study areas. In the table, the variable framers' membership to associations, cooperatives and groups considered includes only those solely established to facilitate the agricultural production of farmers such as input supply/service cooperatives and farmer associations. However, in Ethiopia smallholder farmers can be members of various non-agricultural oriented institutions and organizations such as religious groups (in churches and mosques), *Idir*, *Ikub*[2], and others. It is observed that about 87.4 percent of smallholder farmers are members of agricultural production oriented associations. Such high rate of participation/membership in associations would facilitate communication between farmers and other bodies such as researchers, development agencies and government.

Moreover, results indicate that about 66.4 percent of smallholder farmers got credit services for agricultural activities at the market interest rate. The remaining 33.6 percent of households could not get the service due to various reasons such as absence of the service for the intended purposes, too high interest rate and absence of demand for the credit service for the agricultural production. It implies that most farmers would have the opportunity to access

[2] *Idir and Ikub in Ethiopia are community institutions established for solving financial and social problems, respectively.*

agricultural inputs (such as seeds, fertilizers and farming equipments); education and health care services and buying of agricultural tools and livestock.

Access to market infrastructure is one of the key constraints in successful participation of smallholder farmers in market oriented agricultural production. Moreover, the intensity of their integration is highly dependent on the access to markets. Proximity to the market is one of those key institutional policy variables that must be taken in to account in actions targeting to improve marketing, resource use efficiency and productivity of smallholder framers. Using walking distance to the nearest market as a proxy; results indicated that in the study areas average walking distance to the nearest main market is about 9.94 km. It is indeed an evidence for the study areas that marketing (transaction) and transport costs can substantially be higher. But most importantly, the costs are largely influenced by the quality and access of the road infrastructure. Integration into input and output markets can also be hindered by the distance households to travel to the main market**.**

Table 5: Summary of Institutional Characteristics of Households (N=700)

Characteristic	Response	Frequency (Number of Households)	Percent
Membership (Dummy)	Yes=1	612	87.4
	No=0	88	12.6
Access to Credit (Dummy)	Yes =1	465	66.4
	No=0	235	33.6

Source: Survey Result, 2008

4.1.4 Rate of Inputs Use and Crop Yields

Table 6 presents the main input uses rates and yields for wheat, chickpea and *teff* production. The result shows that wheat is the first widely produced cereal crop followed by *teff*. From the table, it is indicated that 666 households (95.14 percent), 633 households (90.43 percent) and 559 households (79.85 percent) farmers produce wheat, teff and chickpea respectively. This implies that the three crops are indeed the major crops in the study areas.

The average seed rate per hectare for wheat production is about 233.19 kg per hectare with standard deviation of 83.4. It is higher than the recommended level in the extension packages of 150-175 kg/ha. The average seed rate for Chickpea production was about 168.14 kg per hectare with standard deviation of 91.75. However, compared to the recommended rate of maximum 140 kg per ha the seed rate for chickpea in the study areas is relatively higher. The seed rate for *Teff* production was about 82.53 kg per hectare. It is also by far above the extension package recommended rates of 25-30 kg/ha depending on factors such as fertility of soil, seed variety and degree of weed and pest infestation.

The results also indicated that the use of DAP fertilizer in wheat production had a mean value of 149.33 kg. It is observed that the rate is above the recommended level of 200kg of fertilizer (100 kg DAP and 100 kg urea) per hectare. Use of DAP in chickpea production had a mean value of 119.22 kg per hectare where as the use of urea had a mean of 237 kg. In *teff* production, the result indicated that the rate of DAP fertilizer per hectare had a mean of 189.67 kg where as the use of urea mean of 114.34 kg.

Field chemicals include pesticides, insecticides and weed killers were applied in a very limited rate. The use of these chemicals during the survey year showed that on average 0.59, 0.46 and 0.34 liters of field chemicals per hectare were used in wheat, chickpea and *teff* production, respectively.

Labor use for agricultural production activities (includes ploughing, planting, weeding, harvesting and threshing) constitutes both family labor and hired ones. The average labor use rate in man/days for wheat, chickpea and *teff* production were 517.93, 575.14 and 535.26 man days, respectively.

Finally, productivity of crops was computed based on total grain output per unit of land for those who produce the crop and expressed as kg per hectare of land (kg/ha). Accordingly, the average yields for wheat, chickpea and *teff* obtained by the sample farmers were 2568.9, 2143 and 1916.42 kg/ha, respectively. The average wheat yield level in the study areas is higher than the national average yield level of 16.25 quintals/ha or 1625 kg/ha. However, it is by far lower than the research field/potential yield of 44-50 quintals/ha or 4400-5000 kg/ha which implies there is lower level of productivity in the study areas. Moreover, the average productivity of *teff* is also higher than the national average yield of 11.67 quintals /ha or 1167 kg/ha. However, it is by far below the research field yield of 15-27 quintals /ha or 1500-2700 kg/ha.

Generally, the use of above recommended levels of seed rates in chickpea, wheat and *teff* production and consequent below research field yields or potential yields indicates that there is lower level of productivity and potential resource use inefficiency in the study areas.

Table 6: Rate of Input uses and yield for major crops during 2006/07cropping season

Variables	Unit	Wheat (N=666) Mean	Chickpea (N=559) Mean	*Teff* (N=633) Mean
Seed	kg/ha	233.19 (83.393)	168.14 (91.755)	82.53 (84.884)
DAP fertilizer	kg /ha	199.84 (104.29)	119.22 (102.473)	189.67 (129.709)
Urea fertilizer	kg /ha	149.33 (69.929)	237.0 (67.575)	114.34 (81.905)
Field chemical	liters /ha	0.59 (1.608)	0.46 (0.755)	0.337 (1.323)
Labor use	Man days/ ha	517.93 (318.25)	575.14 (474.401)	535.26 (307.97)
Productivity level	Output /ha	2568.9 (1286.4)	2143.00 (1164.45)	1916.42 (1384.76)

Note: Values in the bracket indicate standard deviations
Source: Survey data, 2008

4.1.5 Description of variables for DEA

One of the most critical steps in order to conduct a DEA analysis is careful examination of the output and input variables and establishing an appropriate level of aggregation. It is necessary to aggregate the data to form a smaller number of inputs and output variables. According to Coelli *et al.* (2005) there are important issues to be considered during input and output aggregation processes. Firstly, it is important to ensure that aggregates formed are meaningful. It is necessary to ensure that the aggregates are formed across variables that exhibit similar movements in relative prices or quantities. Secondly, prices data are integral part of the work when multiple outputs are aggregated. Therefore, value aggregation can be formed by the product of price and quantity and summing it over all the commodities included in the aggregate. Therefore, following Coelli *et al.* (2005), in this study aggregation of outputs and inputs was made keeping that values formed are meaningful and price values are incorporated in value aggregation.

Regarding the reconciliation of zero value data in the DEA analysis different, approaches for outputs and inputs were used. Accordingly, for DMUs producing any of outputs (single or multiple positive outputs) regardless of the type and quantity they produced zero level output was taken as zero for analysis. This is due to the fact that outputs can be zero in the DEA analysis. However, unlike zero outputs, zero inputs were treated differently. For DMU having zeros values in the inputs an arbitrary very small positive value greater than zero but less than the smallest positive observation was assigned during analysis. However, the descriptive statistics for variables of DEA were presented before replacement is made.

4.1.5.1 Outputs

The quantity of output was measured using kilograms. The output of a given crop for a DMU was aggregated and presented in Table 7 as the sum of all outputs of a farmer obtained from different plots regardless of differences in variety. Accordingly, a farmer in the study areas produces on average 1347.9 kg of chickpea, 1170.8 kg of *teff* and 1296.0 kg of wheat. When we compare across the three districts, farmers in Lume Ejere district tend to have the highest mean output for chickpea (1651.93kg) and *teff* (1314.13 kg) whereas farmers in Gimbichu district tend to have the highest mean output (1589.73kg) of wheat. On the other hand, farmers in Minjar Shenkora have the lowest mean chickpea output (919.2kg) and wheat which is about 1151.83 kg.

4.1.5.2 Inputs and input Costs

Table 7 presents the description of inputs, their aggregation[3] and associated costs. The total amounts of DAP and urea were measured in kilograms while their costs were expressed in Ethiopian Birr (ETB). DAP and urea fertilizers were aggregated separately due to the fact that these inputs tend to have quantity and price difference. Similarly, the total cost of DAP and urea incurred by the farmer in ETB were calculated as the sum of money spent on each DAP and urea. On average, 245.82 kg of DAP and 144.78 kg of urea was used while the average cost of these inputs were 926.0 ETB and 500.9 ETB for DAP and urea, respectively. When we compare across the three districts, farmers in Lume Ejere seem to have the highest average use of DAP and Urea fertilizers whereas farmers in Gimbichu have the lowest mean level of DAP and Urea

[3] *For detailed explanation on aggregation of outputs, inputs and input costs see appendix (B).*

fertilizers application perhaps due to the low access to fertilizer, market, credit services and information. On the other hand, mean cost of DAP and urea fertilizers used tend to be the highest in Lume Ejere and Gimbicu districts, respectively. Whereas their mean costs and quantity of use was the lowest in Minjar Shenkora district compared to the other two districts.

The size of land used for major crops production in the study areas (Chickpea, *Teff* and Wheat) by each farmer was measured in *kert*. However, for the sake of standardization and aggregation purposes the total land allocated for production of crops for each farmer was converted to hectare using the conversion factor as 1 hectare equivalent to 4 *kert*. The cost of land was approximated by its rental value. On average, the rental value of good quality of land 650 ETB per *kert* or equivalent to 2600 ETB per hectare for one production year was used to estimate cost of land. Accordingly, on average a given household allocate a total of 1.96 hectare of land for chickpea, wheat and *teff* production and its average cost was also computed as ETB 5086.21. Moreover, farmers in Lume Ejere have the highest average size of plot whereas farmers in Minjar Shenkora district seem to have the lowest mean plot size perhaps due to variations in population size and limited arable land in the districts. It is also showed that the mean cost of land used was the highest in Lume Ejere district, whereas it is the lowest in Minjar Shenkora district.

Table 7: Input uses and outputs for major crops across district

Variables	Unit	Lume Ejere (N=300)	Minjar Shenkora (N=251)	Gimbichu (N=149)	Aggregate (N=700)
Output of Chickpea	kilograms	1651.93	919.202	1458.03	1347.893
		(2048.547)	(1123.792)	(1533.89)	(1689.134)
Output of *Teff*	kilograms	1314.13	1268.13	718.562	1170.844
		(1551.759)	(1198.037)	(907.249)	(1331.705)
Output of Wheat	kilograms	1270.83	1151.83	1589.73	1296.045
		(2492.991)	(1124.152)	(1533.252)	(1906.395)
Plot Size	Hectare	2.12	1.69	2.08	1.956
		(1.591)	(0.910)	(1.20)	(1.313)
Labor (Family and Hired)	Man/days	1007.73	701.622	882.012	871.206
		(645.107)	(352.238)	(466.636)	(535.579)
Quantity of Field chemical	Liters	0.91	0.35	0.4625	0.614
		(1.73)	(0.537)	(0.701)	(1.244)
Quantity of Chickpea seed	kilograms	103.16	57.053	153.642	97.373
		(115.286)	(97.461)	(233.347)	(147.934)
Quantity of *Teff* seed	kilograms	81.105	91.728	66.898	81.889
		(88.853)	(129.115)	(121.958)	(112.123)
Quantity of wheat seed	kilograms	83.975	66.1988	117.382	84.712
		(124.788)	(76.4135)	(114.046)	(108.876)
Quantity of DAP fertilizer	kilograms	327.56	161.612	223.102	245.816
		(262.656)	(114.483)	(152.266	(211.259)
Quantity of urea fertilizer	kilograms	172.422	82.799	193.522	144.776
		(176.617)	(66.563)	(143.136)	(146.559)
Cost of Land used	ETB	5505.33	4388.03	5418.63	5086.211
		(4134.865)	(2366.643)	(3120.96)	(3413.637)
Cost of Labor used	ETB	20155.4	14032.4	17640.4	17424.12
		(12902.139)	(7044.765)	(9332.721)	(10711.58)
Cost of field chemical	ETB	72.564	27.782	36.654	48.863

		(138.231)	(43.155)	(56.314)	(99.716)
Cost of chickpea seed	ETB	465.042	257.182	692.602	438.945
		(519.714)	(439.366)	(1051.930)	(666.89)
Cost of *teff* seed	ETB	173.162	195.842	142.822	174.833
		(189.704)	(275.66)	(260.381)	(239.383)
Cost of wheat seed	ETB	348.502	274.722	487.132	351.551
		(517.871)	(317.1186)	(473.291)	(451.838)
Cost of DAP fertilizer	ETB	1207.33	642.722	836.972	926.033
		(1042.448)	(494.798)	(601.164)	(832.71)
Cost of Urea fertilizer	ETB	598.502	283.682	670.052	500.844
		(591.139)	(221.817)	(547.680)	(507.656)

Note: Values in the brackets are standard deviations

Source: Survey data, 2008

On average, about 0.62 liters of field chemical was used during production of the three major crops and its average associated cost was 48.87 ETB. The amount of field chemical application by the farmers was the highest in Lume Ejere whereas farmers in Minjar Shenkora district had applied the lowest amount of field chemical. The mean cost of field chemical applied tends to be highest in Lume Ejere district; whereas it is the lowest in Minjar Shenkora district.

The total amount of seeds used was computed as the sum of different varieties seed of same crop used in different plots from different sources for each crops. The corresponding seed costs were computed as the products of the total amount of seed used and the market prices of a unit kilogram of seed. On average, the amounts of seeds used were 97.37 kg, 81.89 kg and 84.71kg for production of chickpea, *teff* and wheat, respectively. The associated average costs of chickpea, *teff* and wheat seeds were ETB 438.95, 174.84 and 351.55, respectively. Looking across districts, the mean quantity of seed used for chickpea and wheat was the highest in Gimbichu district whereas level of *Teff* seed was the highest in Minjar-Shenkora district. It is also indicated that the mean costs of chickpea and wheat seed were the highest among farmers in Gimbichu, whereas cost of *Teff* seed was the highest in Minjar-Shenkora district.

Labor was aggregated for each farmer in a single unit in man/day. The cost of hired labor was estimated based on the daily average wage rate (20 ETB per day) of the nearby village. As a result, total cost of labor input was the sum of cost of hired labor and opportunity cost of family labor. In aggregate, the average use of labor in man/days was about 871.21 and labor cost has an average of 17424.12 ETB. Across districts, farmers in Lume Ejere district had the highest mean level of labor use whereas farmers in Minjar Shenkora district had the lowest mean labor use. Moreover, the mean cost of labor used was the highest in Lume Ejere district; and it was the lowest in Minjar Shenkora district.

4.1.5.3 A One-Way ANOVA and Kruskal Wallis tests

In this study, a null hypothesis was formulated which states that there is no difference in crops productions across districts. Accordingly, a One-Way ANOVA was used to test the hypotheses. From the result, in Table 8, the F-statistic of the ANOVA test takes the value 13.91 for chickpea and 11.09 for *teff* associated with significant level of 0.000 which exceed the critical F-value of 4.61 with 2 degree of freedom for numerator and 697 for denominator at 1% significant level. However, the F-statistic for wheat output is lower than critical value. Therefore, the result shows that wheat production is not significantly different across districts. However, the Levene statistic to test for the equality of group variances showed that the test is statistical significant for Chickpea and *Teff* outputs implying that there is a significant variation across population variances where the respective samples come from. Thus, it is important to look at the results of an appropriate alternative nonparametric test for chickpea and *teff* outputs such as Kruskal Wallis Test. The Kruskal Wallis test is used to test the null hypothesis that '*k*' independent random samples come from identical universes against the alternative hypothesis that the means of these universes are not equal (Kothari, 2004; Singh, 2007). Accordingly, using the Kruskal Wallis Test with a chi-square distribution, the results for Chickpea and *Teff* outputs are 39.865 and 34.765 which again exceed the critical value of 9.21 with 2 degrees of freedom at 1% level of significance. Consequently, it is concluded that the three districts have different average chickpea and *Teff* outputs which means there is evidence to reject the null hypothesis in favor of the alternative. As a result the hypothesis made in the study on the similarity of major crop outputs across the three districts was rejected for Chickpea and *Teff* outputs in favor of the alterative and it is accepted for wheat output.

Table 8: One-Way ANOVA and Kruskal Wallis tests for Crop Outputs across districts

Output (kg)	ANOVA		Test of Homogeneity of Variances		Kruskal Wallis Test	
	F	Sig.	Levene Statistic	Sig,	Chi-Square	Asymp. sig
Chickpea	13.91	0.000	9.721	0.000	39.865*	0.000
Teff	11.09	0.000	12.493	0.000	34.765*	0.000
Wheat	2.22**	0.110	1.206	0.300		

Note: * and ** are for decisions rejected and accepted, respectively.
Source: Survey data, 2008

4.2 Data Envelopment Analysis Results of Efficiency Scores

Model Specification Tests: the DEA technique used in the estimation of relative efficiency of DMUs was checked for potential problems such as sample size and outliers that can seriously affect the efficiency scores. Given there are 8 inputs (m) and 3 outputs (s) the sample size (n=700) used in the present study by far exceeds the required sample size as suggested by the rules of thumb of ($700 \geq \max(8 \times 3$ or $700 \geq 3(8+3))$ and it is feasible. Following the approach suggested by Tran *et al.* (2008) based on lambda-count or lambda-sum for efficient farms it is observed that there are no outlier sample efficient farms in the study.

4.2.1 Total Technical Efficiency Scores

From Table 9, it is showed that the mean total technical efficiency score of sample farms in the study areas was 0.62. These results imply that if sample farms in the study areas operated at full efficiency level, farmers would have increased their output, by 38 percent using the same level of inputs. This shows there is higher margin of increase in major crops output. The mean pure technical and scale efficiency of aggregate sample farmers were 0.72 and 0.93 scores, respectively. The level of pure technical efficiency indicates that, by excluding the effect of input and output sizes, the producers in the study area can increase their major crops output by 28 percent with current level of inputs. Looking across districts, a higher level of mean total technical efficiency was observed in Minjar Shenkora (0.83) compared to Gimbichu (0.79) and Lume Ejere (0.68). In other words, Lume Ejere district has the highest potential for increasing outputs of major crops. During the analysis it was also noted that district levels of efficiency scores were relatively higher than the aggregated sample efficiency scores. In the other words, as the sample size increases, the estimated level of efficiency scores will decrease showing higher level of potential increase in outputs. Therefore, small sample size may give upward biased estimates of efficiency scores which make some farmers seemingly efficient. Furthermore, it has been found that total technical inefficiency was mainly caused by pure technical inefficiency (poor management) amounting about 28 percent rather than scale inefficiency (too small or too large size) of 7 percent.

Table 9: Frequency Distribution of Total Technical (TE_{CRS}), Pure Technical (TE_{VRS}) and Scale Efficiency (SE) across sample districts

Efficiency Scores	Gimbichu (N=149)			Lume Ejere (N=300)			Minjar Shenkora (N=251)			Aggregate (N=700)		
	TEcrs	TEvrs	SE	TEcrs	TEvrs	SE	TEcrs	TEvrs	SE	TEcrs	TEvrs	SE
0.0-0.1	0	0	0	0	0	2	0	0	0	1	0	1
0.11-0.2	0	0	0	4	1	0	0	0	0	2	1	0
0.21-0.3	2	0	0	14	14	0	1	1	0	30	20	0
0.31-0.4	5	3	0	38	28	0	6	3	1	53	43	0
0.41-0.5	15	10	0	29	27	1	9	8	1	75	57	1
0.51-0.6	9	13	1	51	43	3	20	12	2	92	82	7
0.61-0.7	26	12	2	33	33	14	35	27	5	99	83	23
0.71-0.8	14	24	12	23	29	9	24	22	11	62	78	62
0.81-0.9	10	13	18	20	26	43	31	31	15	61	66	83
0.91-1	68	74	116	88	99	228	125	147	216	223	270	523
Efficient	53	59	90	74	87	128	102	124	152	184	230	348
Inefficient	96	90	59	226	213	172	149	127	99	516	470	352
Mean	0.79	0.83	0.95	0.68	0.72	0.94	0.83	0.87	0.95	0.62	0.72	0.93
STD	0.22	0.2	0.09	0.26	0 .25	0.13	0.19	0.18	0.96	0.25	0.24	0.11

Source: Survey data, 2008

4.2.2 Distribution of Technical, Allocative and Economic Efficiency Scores

Table 10 presents results of aggregate technical, allocative and economic efficiency scores of sample smallholder farmers in the study areas. It is evident that about 395 smallholder farmers (56.43 percent) were technically efficient but about 99 percent of smallholder farmers in the study areas weere both allocativelly and economically inefficient.

Table 10: Aggregate Frequency Distribution of Total Technical (TE), Allocative (AE) and Economic Efficiency (EE) (N=700)

Efficiency Ranges	TE		AE		EE	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
0.0-0.1	0	0	2	0.28	5	0.714
0.11-0.2	4	0.571	54	7.7	114	16.28
0.21-0.3	32	4.57	151	21.57	276	39.43
0.31-0.4	51	7.28	149	21.14	168	24
0.41-0.5	58	8.28	127	18.14	86	12.28
0.51-0.6	57	8.14	72	10.28	30	4.28
0.61-0.7	45	6.43	74	10.56	10	2.85
0.71-0.8	27	3.85	44	6.28	2	0.28
0.81-0.9	22	3.14	13	1.85	1	0.14
0.91-1	404	57.7	14	2.0	8	1.14
Efficient	395	56.43	7	1	7	1
Inefficient	305	43.57	693	99	693	99
Mean Scores	0.79		0.43		0.31	
Minimum	0.14		0.062		0.042	
Maximum	1		1		1	
Std. deviation	0.27		0.19		0.14	

Source: Survey data, 2008

Technical Efficiency (TE)

As it is shown in Table 10, smallholder producers had a mean technical efficiency score of 0.79. The result indicates that on average smallholder producers in the study areas can increase their major crops output by 21 percent using existing resources and level of technology. Figure 5 also illustrates that 404 farmers (57.7 percent) achieved technical efficiency scores between 0.91 and 1.0. Moreover, about 555 farmers (79 percent) have technical efficiency scores above 0.5.

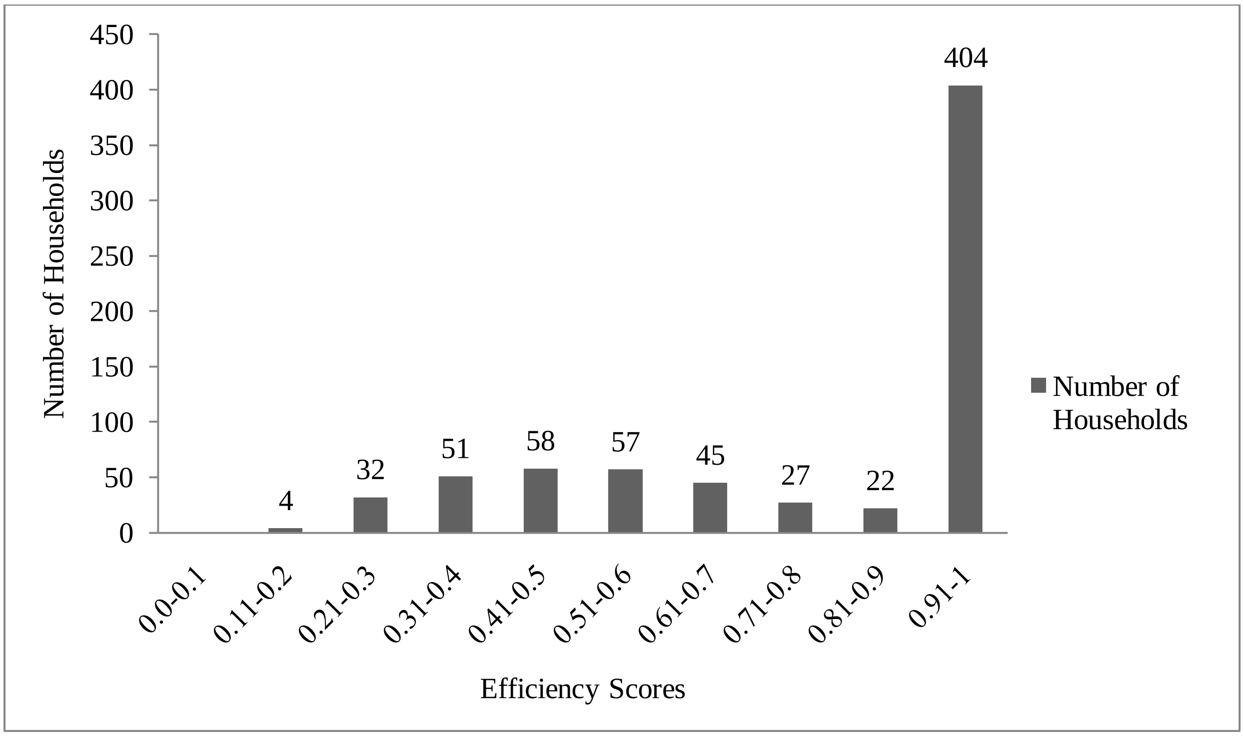

Figure 5: Frequency Distribution of Technical Efficiency Scores in the study areas (N=700)
Source: Survey data, 2008

Allocative Efficiency (AE)

Table 10 also showed that the average level of allocative efficiency score was 0. 43. The result indicates that on average smallholder producers in the study areas could increase major crops output by 57 percent if producers used the right inputs and produced the right outputs relative to input costs and output prices. The distribution of allocative efficiency scores presented in the Figure 6 showed is relatively left skewed. It is also showed that a total of 483 farmers (69 percent) achieved allocative efficiency scores below 0.51.

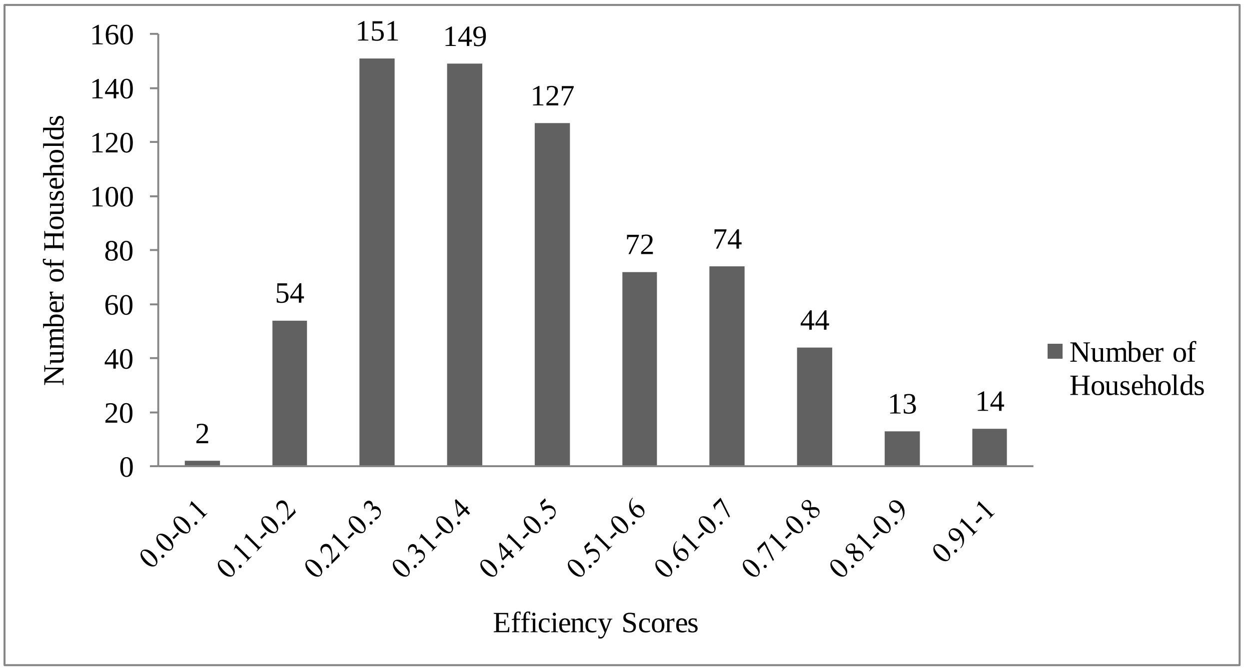

Figure 6: Frequency Distribution of Allocative Efficiency Scores in the study areas (N=700)
Source: Survey data, 2008

Economic Efficiency (EE)

Economic efficiency was estimated for sample farmers using input oriented DEA model. The average score of economic efficiency was 0.31. It is indicated that on average smallholder producers in the study areas could reduce cost of production of crops by 69 percent producing the current level of outputs. Figure 7 also presents a relatively left skewed distribution of economic efficiency scores. It is found that a total of 649 farmers (92.71 percent) had economic efficiency scores below 0.51.

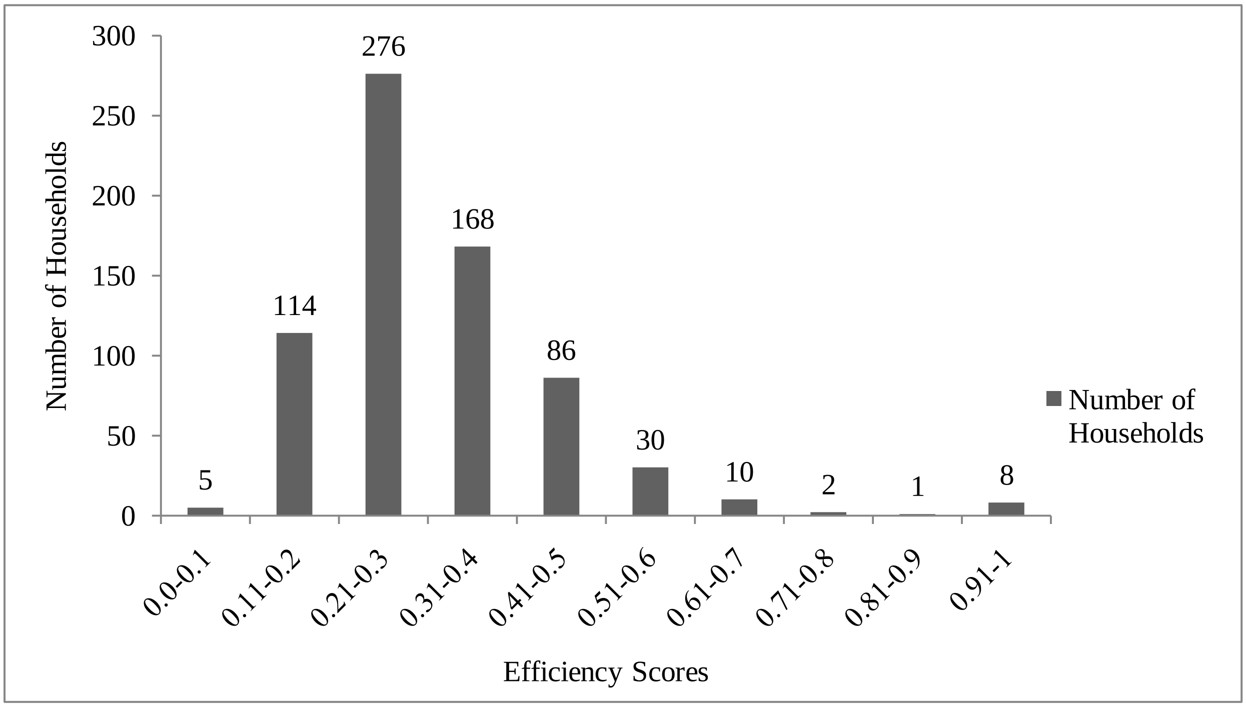

Figure 7: Frequency Distribution of Economic Efficiency Scores in the study areas (N=700)

Source: Survey data, 2008

4.2.3 Hypotheses Testing

4.2.3.1 One-Sample t- Test

The One-Sample *t*- test procedure tests whether the mean of a single variable differs from a specified constant. The test is intended to know if smallholder farmers were technically, allocativelly and economically efficient in the study areas. In this study one-sample t- tests for the null hypotheses that efficiency scores are equal to 1 (farmers are efficient) were tested. Accordingly, the results in Table 11 show that t-values are statistically significant at 1 percent significance level. Consequently, all the null hypotheses were rejected. Therefore, it is concluded that smallholder farmers were not technically, allocativelly and economically efficient.

Table 11: Results for One-Sample t-Test

	t	df	Sig. (2-tailed)	MD	95% CI of the MD	
					Lower	Upper
Technical Efficiency	-20.53	699	0.000	-0.206	-0.225	-0.186
Economic Efficiency	-132.53	699	0.000	-0.689	-0.699	-0.679
Allocative Efficiency	-78.48	699	0.000	-0.570	-0.583	-0.555

Note: MD stands for Mean Difference and CI is for Confidence Interval

Source: Survey data, 2008

4.2.3.2 A One Way ANOVA and Kruskal Wallis Tests

For the null hypothesis which states that technical efficiency scores across districts are equal was tested using One-Way ANOVA. However, the Levene statistic indicated that the test is statistical significant for technical efficiency scores. Thus, the Kruskal Wallis Test was employed and the result showed that chi-square value of mean technical efficiency was 41.39 which exceed the critical value of 9.21 with 2 degrees of freedom at 1% level of significance. Consequently, it is concluded that technical efficiency scores significantly vary across districts. As a result the null hypothesis is rejected in favor of the alternative hypothesis. Moreover, a One-Way ANOVA test was conducted to know if there is significant variation in allocative efficiency scores across districts. The F-statistic takes the value 32.6 with associated significant level of 0.00 that exceeds the critical F-value at 1% significant level showing that the difference is significant at 1 percent significance level. Consequently, the null hypothesis was rejected. Moreover, the Levene statistics revealed that the test is statistical insignificant. Finally, using appropriate a non-parametric Kruskal Wallis Test, the result suggests that economic efficiency scores were significantly different across districts; as a result the null hypothesis was rejected in favor of the alternative hypothesis. In general, in contrary to the hypotheses of the study, the tests showed that there is significant variation in efficiency scores across the three districts under consideration (Table 12).

Table 12: A One-Way ANOVA and Kruskal Wallis Tests for Efficiency Scores across Districts

Efficiency Scores	One-Way ANOVA		Test of homogeneity		Kruskal Wallis	
	F-value	sig. level	Levene Statistic	Sig. level	Chi-square	Asymp.sig
TE	34.2	0.000	91.84	0.000	41.39*	0.000
AE	32.6*	0.000	1.792	0.167		
EE	94.1	0.000	17.386	0.000	31.85*	0.000

Note: * shows the test is significant at 1 % significance level so that all the hypotheses were Rejected.
Source: Survey data, 2008

4.2.4 Distribution of Returns to Scale

Returns to scale explains the responsiveness of agricultural outputs to simultaneous changes in the input use. Three different types of returns to scale as increasing, constant and decreasing returns to scale were estimated in this study. Figure 8 presents the results on the distribution of returns to scale across districts. At aggregate level, the results show that about 50% of sample farmers in the study areas operated under constant returns to scale. It implies that about 50 percent of smallholder farmers in the study areas are operating at most productive (optimal) scale size. Moreover, 37 percent of farmers operate under decreasing returns to scale or above-optimal size. Thus, downsizing of their scale of agricultural operation seems to be an appropriate strategic option to increase production and productivity via efficient input use. Generally, it is established that decreasing returns to scale or the use of above optimal level of inputs is found to be the predominant form of scale inefficiency in the study areas. This finding confirms with the findings of this study about of above-recommended rate of input uses by smallholder farmers. Comparing across districts, 62, 45 and 61 percent of farmers operate under CRS in Gimbichu, Lume Ejere and Minjar Shenkora districts, respectively. On the other hand, 29, 44 and 24 percent DRS. in Gimbichu, Lume Ejere and Minjar Shenkora districts, respectively. Therefore, unlike the priori expectation about returns to scale of farmers, it is found that half of the farmers were experiencing either increasing or decreasing returns to scale. Therefore, the hypothesis which claimed that smallholder farmers operate under constant returns to scale was rejected.

Generally, it is found that the proportion of farmers operated under increasing returns to scale is relatively lower in all districts compared to those who are experiencing constant and increasing returns to scale in the respective districts. Therfore, policies and strategies targeting expanding supply and access to inputs should also consider the redistribution of resources to resource poor or who are operating at suboptimal stage of production. Moreover, since dacreasing returns to scale is an evidence for resource is being wasted, trainings on recommended input use should be delivered to farmers.

Table 13: Distribution of Returns to Scale across districts

Returns to Scale (RS)								
	Gimbichu		Lume Ejere		Minjar Shenkora		Aggregate	
RS	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
CRS	92	61.75	135	45	154	61.35	353	50.43
DRS	43	28.85	133	44.34	59	23.5	258	36.86
IRS	14	9.4	32	10.667	38	15.14	89	12.7
Total	149	100	300	100	251	100	700	100

Note: CRS, DRS, and IRS in the Table 13 and Figure 8 refer for Constant, Decreasing and Increasing Returns to Scales, respectively.

Source: Survey data, 2008

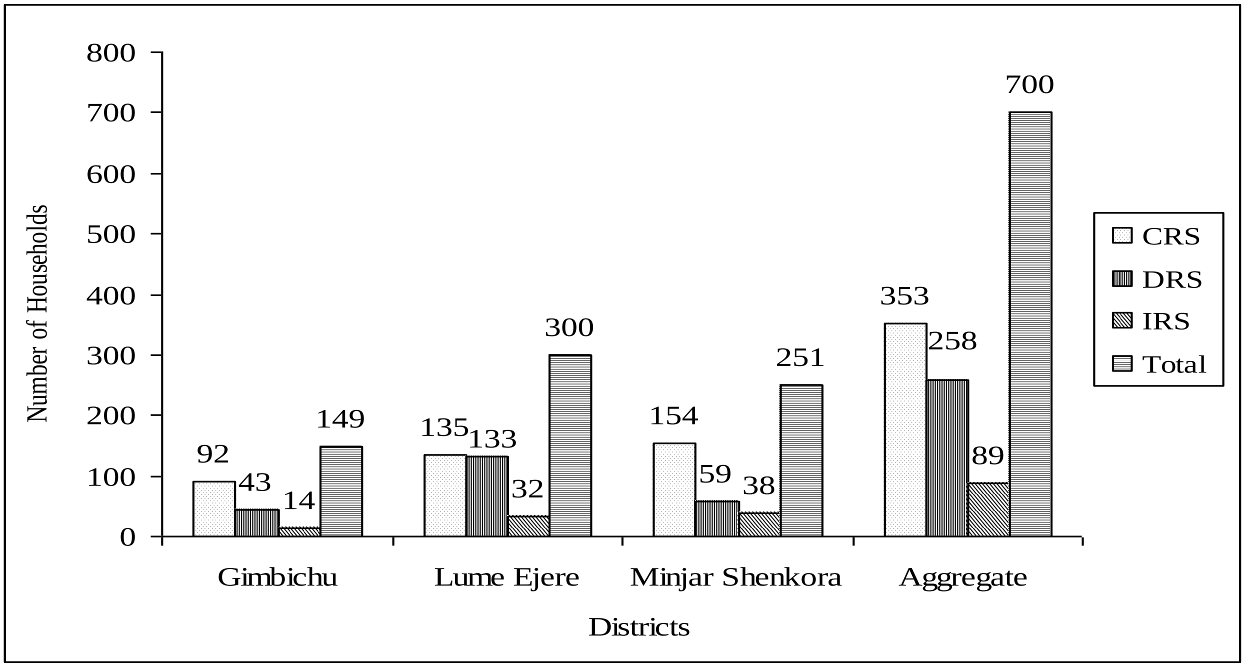

Figure 8: Distribution of Returns to Scale across Districts

Source: Survey data, 2008

4.3 Econometric Results for Tobit Regression Model

Table 14 presents the descriptive statistics for demographic, socioeconomic and institutional variables which were expected to affect technical and economic inefficiency levels of smallholder farmers. In this study factors such as farmer characteristics (level of education, age, sex, role of the household head in the community, farming experience); farm characteristics (land size and plot distance) and demographic, socio economic and institutional factors (family size, contacts with extension agents, walking distance to the nearest main market, access to credit and membership to associations) were included.

Education level is measured as the numbers of years that the household head stayed in school either in a formal or informal education systems. It was assumed that the higher the level of education, the better the managerial capability of the head will be. Smallholder farmers with more years of schooling were expected to have less technical and economic inefficiency. Therefore, the expected sign of coefficient for education level on inefficiency was negative. From Table 14, mean education level **(hheadeduc)** of household heads was 1.74 years. Looking across districts, the value seems to be the highest in Gimbichu district having 2.3 years whereas it is the lowest in Minjar-Shenkora district as 1.29 years.

Table 14: Descriptive Statistics of variables for Two-Limit Tobit Regression Model

*Continuous Variables**	Lume Ejere (N=300)	Minjar Shenkora (N=251)	Gimbichu (N=149)	Aggregate (N=700)
	Mean	Mean	Mean	Mean
Age of the hhh (years)	47.63 (12.70)	47.02 (12.46)	46.54 (12.4)	47.18 (12.54)
Education level of hhh (years)	1.83 (2.91)	1.29 (2.11)	2.32 (3.00)	1.74 (2.69)
Family size (number)	6.73 (2.46)	6.00 (2.07)	6.39 (2.23)	6.40 (2.29)
Plot distance from residence (Km)	1.46 (1.43)	1.82 (2.59)	1.85 (2.09)	1.67 (2.05)
Experience of growing chickpea (years)	22.53 (12.52)	17.97 (12.83)	19.9 (10.56)	20.34 (12.39)
Walking distance to the nearest main market (km)	11.97 (11.86)	8.42 (9.21)	8.41 (3.68)	9.94 (9.83)
Number of Contacts with extension agents (days/year)	21.81 (31.78)	16.44 (17.79)	24.9 (34.17)	20.56 (28.36)
Own cultivated land Size (ha)	2.37 (1.66)	1.77 (1.08)	2.04 (1.32)	2.08 (1.43)
Dummy Variables*	Freq.	Freq.	Freq.	Freq.
Sex of the hhh				
Male (1)	276 (92)	234 (83.67)	140 (93.96)	650 (92.85)
Female (0)	24 (8)	17 (16.33)	9 (6.04)	50 (7.15)
Role of hhh in the Community				
Yes (1)	92 (30.66)	48 (19.12)	40 (26.85)	180 (25.7)
No (0)	208 (69.34)	203 (80.88)	109 (73.15)	520 (74.3)
Membership of household in to associations				
Yes (1)	263 (87.67)	208 (82.87)	141(94.63)	612 (87.43)
No (0)	37 (12.33)	43 (17.13)	8 (5.37)	88 (12.57)
Access to Credit				
Yes (1)	205 68.34)	150 (59.76)	110 (73.83)	465 (66.43)
No (0)	95 (31.66)	101 (40.14)	39 (26.17)	235 (33.57)

Note: * and ** under *continuous* and *dummy* variables indicate that the values in the brackets are standard deviations and percents, respectively; and hhh stands for household head.

Source: Survey data, 2008

Age of household head **(age)** was also included in the model to reflect the managerial ability that stems from experience. It is presumed that older farmers are likely to have more experiences in production and marketing of crops which can lead to less inefficiency than younger ones. On the contrary, it can also be argued 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. However, age was expected to have a negative sign in this study. This is due to the fact that adoption of new technologies by older farmers can also be achieved through experience. In this study, mean level of household heads age was 47.2 years. This value was the highest in Lume Ejere and the lowest in Gimbichu districts with 47.63 years and 46.54 years, respectively suggesting that there is similar age distribution across districts.

The variable number of contacts with extension agents (days per year) **(contextag)** was used to look in to the effect of availability of extension services on efficiency level of farmers. It is commonly believed that those farmers who have more contacts with extension agents are technically and economically more efficient than those who have less/no contacts with extension agents. Hence, expected sign of this variable was negative. On average, a smallholder farmer had about 20.56 days of contacts per year. It was the highest in Gimbichu district and the lowest in Minjar Shenkora district with 24.9 and 16.44 days per year, respectively.

The effect of sex on production inefficiency of famers (**gender)** was included as a dummy variable. There is difference in perception and reaction to any deal and the consequent decisions between male and female household heads. But no priori expectation of sign was made for sex difference. In this study, out of all respondents 92.85 percent were male headed households. It is the highest in Gimbichu (93.96 percent) and the lowest in Minjar Shenkora (83.67 percent).

Walking distance to the main market (km) **(wlkdsmnm)** was used to incorporate the effect of the development of roads and market infrastructures on the technical and economic inefficiency. It is assumed that farms located closer to the market are more technically and economically efficient than their counterparts located far from the market. On average, to reach the nearest main market households have to travel 9.94 km. It is relatively farther in Lume-Ejere district which is about 11.9 km while it is about 8.4 km for Gimbichu and Minjar Shenkora districts.

The variable access to credit service (dummy) **(creditacc)** was used to look into the effect of availability of credit on technical and economic inefficiency of farms. Access to credit was supposed to reduce the technical and economic inefficiency levels of farmers. In the study areas, 66.7 percent of households got credit service with market interest rate. Moreover, the proportion of households who had access to agricultural credit services was the highest in Gimbichu district as 73.83 percent and the lowest in Minjar Shenkora district as 59.76 percent.

Family Size **(familysize)** was measured by the total number of number of persons in the household. Family could have positive effect in raising labor availability hence efficiency of the farmer in the production of crops. This is because a household that has large family size can carry out important agricultural practices timely. Therefore, expected sign of this variable was negative. In the study areas, the average family size of respondents was found to be 6.4 persons per household. It was relatively larger in Lume Ejere district (6.73) whereas it was relatively lower in Minjar Shenkora district as 6.00 persons per household. However, the difference across districts is relatively small showing similar population distribution across study areas.

Farmers' experience in chickpea production since formed a family **(farmexpr)** was used as a proxy for farmers' ability in resource allocation and as a proxy for experience of major crops growing. As farmers spend longer time in crops production, they will better understand the production process and also time of marketing for better return. This variable also help to capture the general knowledge of the producer in understanding to select and allocate land for various crops that ultimately affects his/her efficiency. It was found that farmers had a mean value of 20.34 years of chickpea growing experience. The mean years of experience of growing was found relatively higher in Lume Ejere district which was about 22.53 years whereas it was lower in Minjar shenkora district as 17.97 years.

Land size cultivated for crops in the long rainy season **(cultrany)** was included in the model to capture how the size of land cultivated affects efficiency of the producer. It was hypothesized that economic and technical inefficiency levels increase as size of the farm increases. The average cultivated plot size was 2.08 hectares. However, farmers in Lume-Ejere found to have larger average cultivated area (2.37 ha) whereas it was the lowest in Minjar Shenkora (1.77 ha).

Smallholder producers in the rural areas handle different community roles **(rolecommu)** like administration, security, membership to committees, leaders and chairpersons in different farmers groups, associations and clubs. Some roles may help farmers to have relatively more contacts and participate in trainings compared to other farmers. On the contrary, taking a responsibility in the community might have a trade off of time between farming practice and time spent on the discharge of the duty. This may increase inefficiency due to low attention to farming practice. On average, 25.7 percent of household heads had a role in their community. The proportion tends to be the highest in Lume Ejere district (30.66 percent) and the lowest in Minjar Shenkora district (19.12 percent).

Membership to associations, cooperatives and farmers' groups **(membership)** is one of the channels through which new technologies are transferred to farmers. It is expected that farmers who are members of associations will help them to reduce their technical and economic inefficiency levels. In the study areas in aggregate, it is found that 87.4 percent of farmers were members of farmers associations and cooperatives. It was relatively the highest in Gimbichu district (94.63 percent) and the lowest in Minjar Shenkora district (82.87 percent).

The variable average plot distance from residence **(Plotdist)** was included to see how the location of plots from the residence affects efficiency of farmers. It is expected that as plots located farther from residence, it will not be visited as frequent as those found relatively nearby the residence. In the study areas, on average, plots are located with 1.67 km distance from residence of sample households. However, it was about 1.85 km in Gimbichu district and 1.45 km in Lume Ejere district which shows relatively similar distances of plots from residence.

Model Specification tests: Test of the appropriateness of the model and the explanatory variables included in the model is the next critical step before analysis and drawing implications. Taking in to account the very nature of the data used (cross sectional); tests for multicollinearity, heteroscedasticity and endogeneity problems were conducted.

Multicollinearity Test: Multicollinearity problem arises when at least one of the independent variables is a linear combination of the others. The existence of multicollinearity problem can cause the estimated regression coefficients to have the wrong signs and smaller t-ratios that might lead to wrong conclusions. Rabe-Hesketh and Everitt (2000) indicated that a strong linear dependence (correlation coefficient) might be a source of collinearity problems and can be investigated further by calculating Variance Inflation Factor (VIF) for each of the explanatory variables. Chatterjee and Price (1991) gave the 'Rules-of-Thumb' for evaluating the existence of Multicillinearity problem in the model. The authors suggested that if VIF values are larger than 10 or if a mean of the factors (1/VIF) considerably larger than one; there is evidence of Multicollinearity problem that calls for serious concern. Accordingly, VIF values were computed for all continues variables and they were ranging between 1.16 and 7.14. Moreover, the values of mean of the factors (1/VIF) found between 0.14 and 0.86. Hence, multicollinearity was not a problem among the continuous variables. Furthermore, the mean VIF of 2.94 shows the problem of multicollinearity problem in the model is no longer a serious problem (Table 15).

Table 15: Multicollinearity Test Results for Continuous dependent Variables (N= 700)

Variables	VIF	1/VIF
Age of the Household Head	7.14	0.14
Education level of the household head	1.16	0.86
Family size	4.76	0.21
Average Plot distance from Residence	1.28	0.78
Farm Experience	3.84	0.26
Walking distance to the nearest main market	1.45	0.69
Number of contacts with government extension agent	1.29	0.78
Total own land cultivated during long rainy season	2.63	0.38
Mean VIF	2.94	

Source: Survey data, 2008

Similarly, the underlying assumption that there is no directional relationship between variables in the two-limit tobit regression model was checked for dummy variables as well. Following Blaikie (2003) a contingency coefficient which is derived from chi-square (χ^2) was used to test the null hypothesis that there is no directional relationship between dummy variables in the two-limit tobit regression model. The results in Table 16 shows that the coefficients vary between 0.009 and 0.134 that indicates there is no evidence for strong correlation between the dummy variables.

Table 16: Contingency coefficient results for dummy dependent variables (N=700)

Dichotomous Variables	gender	membership	rolecommu	creditacc
gender	1.000			
membership	0.054	1.000		
rolecommu	0.112	0.012	1.000	
creditacc	0.009	0.134	0.023	1.000

Source: Survey data, 2008

Heteroscedasticity Tests: Maddala and Nelson (1975) showed that the ML (Maximum Likelihood) estimators of tobit regression model are inconsistent if there is heteroscedasticity problem. Maddala (1983) illustrates the effects of heteroscedasticity in estimates for various models and Arabmazar and Schmidt (1981) provided further analysis on the robustness of the ML estimator to the heteroscedasticity. However, Maddala and Nelson (1975), Hurd (1979), Arabmazar and Schmidt (1982), and Brown and Moffitt (1982) all have varying degrees of pessimism regarding how inconsistent the maximum likelihood estimator will be when heteroscedasticity occurs (Greene, 2003). The first step in addressing the problem of heteroscedasticity is to determine whether or not heteroscedasticity actually exists. Therefore, following the techniques mentioned by Peter (1998) to identify the problem of heteroscedasticity, a visual inspection of residuals method was used to detect the problem and the result from observation showed absence of heteroscedasticity in the data.

Endogeneity Problem Test: When variables are endogenously determined in the economic sense, there is also a strong chance that they will be endogenous in the statistical or technical sense, namely correlated with the disturbances in the structural equation. Endogeneity problem exists when an independent variable in the model is explained by another variables included within the equation. Neglecting the problem of endogeneity in the equation introduces a simultaneity bias. Therefore, in this study, restricted models were estimated in which the direction of the signs and significance levels changed, and the coefficients deviated though not significantly. Thus, the restricted models showed that some of the independent variables were suspected to be explained within the model in which it appeared. This implies potential endogeneity is a problem in the model. Hence, to avoid the problem few variables suspected of causing the problem were dropped and consistence was achieved.

4.3.1 Sources of Technical Inefficiency

Table 17 presents results for sources of technical inefficiency. The log likelihood statistic which measures the fit of the model shows that the model is appropriate given its significant chi-square ($p<0.001$) and the large absolute value of Log Likelihood ratio. It is shown that while age of the household head negatively and significantly affects technical inefficiency; walking distance to the nearest main market, family size, farming experience, credit access and total land cultivated affect technical inefficiency level positively and significantly. The result is in line with the priori expected sign of age of the household, walking distance to the nearest main market and total own land cultivated but it is in contrary for family size, farming experience and credit access.

The age of household head negatively and significantly (at 1 percent significance level) affects technical inefficiency of farmers. This result implies that older farmers are technically more efficient than younger ones. Coelli (1996a) concludes that the age of a farmer can be expected to have a positive or a negative effect on the size of the inefficiency effects. The marginal effect of the variable age implies other variables keep unchanged; a year increase in the age of a household head decreases the expected value of technical inefficiency by a score of 0.0031 at 1 percent significance level. The findings of this study confirms with that of Battese *et al.* (1996), Llewelyn and Williams (1996), Getu (1997), Mohammad *et al.* (1999), and Mersha (2004) where age was found negatively and significantly affect resource use inefficiency. However, it is in contrary to the results reported by Alene and Hassan (2002) and Okoye, *et al.* (2007).

Table 17: Two-Limit Tobit Regression Model results for Sources of Technical Inefficiency

Independent variables	Coefficients	Std. Err.	*t*	P-value	$\left(\partial y / \partial x\right)$
Sex of the Household Head	0.1024	0.0880	1.16	0.248	0.0446
Age of the Household Head	-0.0070***	0.0025	-2.74	0.006	-0.0031
Education level of the household head	-0.0043	0.0085	-0.50	0.619	-0.0019
Family size	0.035***	0.0103	3.37	0.001	0.0153
Plot Distance from residence	-0.0011	0.0101	-0.10	0.917	-0.0005
Farming experience	0.0095***	0.0025	3.78	0.000	0.0042
Walking distance to the nearest main market	0.0042**	0.0021	1.98	0.048	0.0018
Membership of household	-0.0386	0.0660	-0.58	0.559	-0.0168
Role of household head in the community	0 .056	0.0491	1.13	0.259	0.0244
Contacts with extension agents	-0.0009	0.0008	-1.14	0.255	-0.0004
Credit Access	0.128***	0.0465	2.75	0.006	0.0558
Total own land cultivated	0.049***	0.0165	2.96	0.003	0.0214
Constant	-0.399***	0.1528	-2.61	0.009	
Log Likelihood	-462.28			0.000	
N	700				
Scale Factor for Effects	0.436				

Note: ** and *** significant at 5 and 1% level, respectively.
Source: Survey data, 2008

Farming experience was also found to be statistically significant at 1 percent significance level. It has a positive effect on technical inefficiency level. The sign of the variable is in contrary to priori expectation. The result implies that farmers with longer experience of chickpea production are more technically inefficient compared to those having lower production experience. This scenario can occur if older farmers in chickpea production are conservative for new technologies and stick to traditional production system while younger farmers are more risk takers, open to new technologies and not tied with traditional production systems. The marginal effect of the variable farming experience implies that, other variables keep constant, for a year increase in farming experience increases the expected value of technical inefficiency by a score of 0.0042 at 1% significant level.

The walking distances to the nearest main market was found to have a positive and significant effect on technical inefficiency at 5 percent significance level. Positive sign of parameter for this variable is similar to the priori expectations of the study. The result suggests that technical inefficiency of sample farms would significantly decrease with the development of road and market infrastructure that reduce home to market distance. According to FAO and IFA (1999), the utilization of purchased inputs would have been higher in developing countries if the supply outlets were made available to the farming communities at a walking distance. Ghura and Just (1992) also argue that only price incentives are not adequate to enhance supplies of agricultural commodities unless these measures are supplemented with continued investment in rural infrastructure. The finding also confirms with that of Javed (2009) but in contrary to the finding of Alemu *et al.* (2009).

Access to credit was found to have a significant and positive effect on technical inefficiency at 1 percent significance level. The sign is in contrary to the expectation. Other variables keep constant, for a household head having access to credit increases the expected value of technical inefficiency by a score of 0.0558 at 1 percent significant level. Perhaps the reasons for the unexpected sign can be some farmers may divert the financial loan obtained from the credit providing institutions. In addition, existing credit institutions in rural Ethiopia provide short-term credit mainly for the purchase of modern fertilizers and improved seeds, while there is a serious credit problem for long term investments such as land improvement. Formal credit institutions currently also require that loans for agricultural inputs should be repaid immediately after harvest which forces farmers to sell their produce when prices are low. On the other hand, perhaps, the state controlled credit systems and input supply could have negatively impacted on the timeliness and quality of services that could also be one of the reasons why its impact is positive and significant to technical inefficiency. Similar result was also obtained by Seyoum *et al.* (1998) and Goibov *et al.* (2010). However, studies by Ekayanake (1987), Parikh and Shan (1994), Alene and Hassan (2002), Idiong (2007), Javed (2009) and Nyagaka *et al.* (2010) concluded that access to credit either reduces inefficiency or increases efficiency.

Total land cultivated was found to have a positive and significant effect on technical inefficiency at 1 percent significance level. The result implies that as farm size increases technical inefficiency level of the farmer will also increase significantly. Other variables keep constant, for a hectare increase in land size increases the expected value of technical inefficiency by a score of 0.0214 at 1 percent significance level. Large farm size was also reported to have a positive and significant effect on inefficiency by Parikh and Shan (1994) in Pakistan and larger farm size reduces economic efficiency by Okoye, *et al.* (2007) in Nigeria. However, the result is in contrary to the findings of Bayou (1999), Mohammad *et al.* (1999) and Seyoum *et al.* (1998).

4.3.2 Sources of Economic Inefficiency

Table 18 presents results of factors affecting economic inefficiency. The log likelihood statistic shows that the model is appropriate given its significant chi-square ($p<0.001$) and the large value of log likelihood ratio.

Family size is found to affect economic inefficiency level positively and significantly at 1 percent significance level. The sign is in contrary to the priori expectation. This situation can occur due to various reasons. Firstly, if there is poor managerial ability to effectively utilize the available labor force in the family, large family becomes costly instead of facilitating production. Secondly, the constituents of the household members also matters. If there are more dependant members in the family (younger than 16 years and older than 65 years) the larger family size is higher burden for the productive household members. This increases economic/ cost inefficiency.

Table 18: Two-Limit Tobit Regression Model results for Sources of Economic Inefficiency

Independent Variables	Coefficients	Std. Err.	*t*	P-value	$\left(\partial y / \partial x\right)$
Sex of the Household Head	-0.0064	0.0204	-0.32	0.753	-0.0063
Age of the Household Head	-0.00014	0.00058	-0.24	0.813	-0.00014
Education level of the household head	-0.0014	0.00204	-0.69	0.493	-0.0014
Family size	0.0098***	0.0025	3.94	0.000	0.0097
Plot Distance from residence	-0.0038	0.0025	-1.51	0.131	-0.0038
Farming experience	0.00114**	0.00056	2.03	0.042	.00113
Walking distance to the nearest main market	0.00063	0.00053	1.18	0.238	0.00062
Membership to associations	0.0328**	0.0158	2.08	0.038	0.0325
Role of head in the community	-0.0233*	0.0121	-1.93	0.053	-0.0231
Contacts with extension agents	-0.00024	0.0002	-1.22	0.224	-0.00024
Credit Access	-0.0081	0.0109	-0.74	0.458	-0.0080
Total own land cultivated	-0.00365	0.0042	-0.87	0.384	-0.00361
Constant	0.613***	0.0353	17.37	0.000	
Log likelihood	390.67			0.000	
N	700				
Scale Factor for Effects	0.99				

Note: *, **, *** significant at 10, 5 and 1% significance level, respectively.
Source: Survey data, 2008

Farming experience also found to have positive and significant effect on economic inefficiency level at 5 percent significance level. The sign of the variable is in contrary to priori expectation. The result implies that farmers with longer experience of chickpea production are more economically inefficient compared to those having lower production experience. This scenario can happen if older farmers in chickpea production are conservative for new technologies and stick to traditional production system while younger farmers are more risk takers and open to new technologies.

The variable membership of household to associations was also statistically significant and has a positive sign. The sign is in contrary to the priori expectation. The result shows that membership to farmers' institutions will positively and significantly increase economic inefficiency levels. It was expected that membership to associations and cooperatives has an added advantage on the access to information and inputs on the timely manner. However, if the information provided, if any, is not accurate or partially accurate and if the input supply and market access through them is not effective the ultimate result is increase in economic inefficiency. Moreover, even where there is participation and membership including of marginalized groups in associations it is not a guarantee for improvements in their productivity and resource use efficiency. Agrawal (2001) differentiates between nominal participation, essentially membership in a community group for mere representation, and active participation. In the case of active participation or membership the powerless and marginalized actually have a voice in decision-making processes, thus leading to equality and empowerment. On the basis of research findings in India and Nepal on community forestry groups and water user groups by Ahmed (2001), Agrawal (2001), and Mohanty (2004) all concluded that women's participation and membership to associations is generally nominal. This leads to few changes being made in gender resource-related roles, as well as responsibilities and rights at the household level. In such cases nominal membership or participation in associations could contribute to even more level of economic inefficiency. This was also the case in the study areas where group membership was primarily dominated by men. However, even if women participated, they may not be active members and few individuals, mainly men, might have dominated the decision-making process where the need of the majority is compromised.

Role of the household head in the community affects economic inefficiency negatively and significantly at 10 percent significance level. The result implies that farmers taking role in the community are less economically inefficient relative to those with no responsibility. In other words, other factors keep constant, for a household head having a role in the community decreases the expected value of economic inefficiency by a score of 0.0231 at 10 percent significance level. This may be due to the reason that those farmers are at the front of new changes in the community. They are supposed to be the first to adopt new technologies; replace traditional production practice with new ones and are considered role models for the rest. This ultimately increases their productivity and hence reduces inefficiency. Recent global studies have also emphasized the need for governance reforms to improve decision-making in rural development. The focus was on decentralization of authority for managing resources and delivering services in rural areas (World Bank, 2003). The study result also supports the views of international commitments to rural development and to addressing environmental and resource degradation via meaningful participation of local people in their planning and implementation processes (Sayer and Campbell, 2004).

4.3.3 Prioritization of Significant Variables

In Table 19, significant variables from the above two tobit regression model analyses were categorized as double effect and single effect variables and prioritized according to their importance. Those factors which significantly affect technical and economic inefficiency in the same direction were grouped under double effect variables. This is due to the fact that policies and programs focused on the improvement of these variables have a simultaneous effect both on technical and economic inefficiency level of farmers in the same direction. On other hand, if the variable significantly affects either technical or economic inefficiency, it is under a single effect variable group. However, there were no significant variables which affect technical and economic inefficiency of farmers in opposite directions which could have called for trade off between objectives.

Table 19: Summary of significant Variables according to their importance

Variable	Technical Inefficiency		Economic Inefficiency	
	Direction	Sig. Level	Direction	Sig. Level
Double Effect Variables				
Family size	Positive	1 percent	Positive	1 percent
Farming experience	Positive	1 percent	Positive	5 percent
Single Effect Variables				
Credit Access	Positive	1 percent	Negative	Not sig.
Total own land cultivated	Positive	1 percent	Negative	Not sig.
Age of the Household Head	Negative	1 percent	Negative	Not sig.
Walking distance to the nearest main market	Positive	5 percent	Positive	Not sig.
Membership of household to associations	Negative	Not sig.	Positive	5 percent
Role of the household Head in the community	Positive	Not sig.	Negative	10 percent

Source: Survey data 2008

Under double effect variables family size and farming experience were the only significant variables which simultaneously affect technical and economic inefficiency of farmers in the study areas. In this study family size was found to have a positive and significant effect on technical and economic inefficiency. The average family size in the study areas was 6.4. This is relatively above the national average family size of 5.2 persons per household. On the other hand, the larger family size in the study areas was not efficiently used to maximize outputs and reduce cost of production. Consequently, larger family size, perhaps either due to input congestion or higher level of dependence ratio, led to technical and economic inefficiency. Therefore, following its double effect nature of the variable, family size was considered as one of the most critical policy variable in the study areas. Any measure to improve the state of family size in the study areas would have a greater policy return due to its simultaneous effect on technical and overall efficiency. Policies targeting family planning, health care, training, and access to education would reduce the burden of dependent family members and hence increase resource use efficiency in the study areas.

Farming experience was also found to have a positive and significant influence on both technical and economic inefficiency of smallholder farmers. It was one of those variables which have a simultaneous effect on technical and overall inefficiency. The result indicated that, in the study areas, older farmers are more technically and economically inefficiency relative to younger ones. Thus, policies aiming at improving efficiency of older smallholder farmers would have a double effect. Policies that facilitate access to reasonable input and output pieces (market access), training on new technologies, improvements in indigenous knowledge and effective way of technology communication with farmers among others would bring a reduction in inefficiency of smallholder farmers through farming experience.

Among the eight significant variables; credit access, age of the household head, walking distance to the nearest main market and total area cultivated significantly affect technical inefficiency hence categorized as under single effect group. Moreover, membership of the household to the associations coops and groups and role of the household head in the community have a significant effect on economic inefficiency. As a result, policies, programs and development interventions targeting the improvement of this group of policy variables would improve either technical or economic efficiency significantly. Accordingly, improvements in credit access, access to cultivable land and market infrastructure will significantly affect only technical efficiency of smallholder farmers. On the other hand, policies targeting the settings of farmers' associations and encourage community-based agricultural activities will significantly affect only economic efficiency.

In conclusion, in contrary to the initial hypothesis-four, based on the above prioritization of variables it is established that demographic, socio economic and institutional factors considered in this study affect technical and economic inefficiency differently except family size and farming experience.

CHAPTER 5

CONCLUSIONS AND POLICY IMPLICATIONS

5.1 Conclusions

This study was conducted to estimate resource use efficiency and determine the underlying factors influencing inefficiency in resource use in Chickpea, *Teff* and Wheat production in the central highlands of Ethiopia. The data were originated from a baseline survey conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Ethiopian Institute of Agricultural Research (EIAR) in three districts namely Minjar-Shenkora, Gimbichu and Lume-Ejere. Data Envelopment Analysis (DEA) approach to estimate the relative efficiency scores and a two-limit Tobit model to determine the sources of resource use inefficiency were used. Various tests were conducted to prove the working hypotheses.

Accordingly, a One-Way ANOVA and Kruskal Wallis test results concluded that there is significant variation in chickpea and *teff* production output across districts. Whereas, the tests revealed that wheat production does not significantly vary across district. Consequently, the hypothesis made in the study on the similarity of major crop outputs across the three districts was rejected for Chickpea and *Teff* in favor of the alterative and it is accepted for wheat output.

Results of one sample *t*-tests, to check whether smallholder farmers are efficient, show that *t*-values are statistically significant at 1 percent significance level. Consequently, all the null hypotheses which claimed that smallholder farmers are efficient were rejected. Therefore, it is concluded that smallholder farmers were technically, allocativelly and economically inefficient.

Moreover, using a One-Way ANOVA and Kruskal Wallis test, it is established that, in contrary to the hypothesis of the study, there is significant variation in resource use efficiency across the three districts under consideration.

In addition, it was also found that about 50 percent of smallholder farmers in the study areas were operating at most productive (optimal) scale size. However, 37 percent of farmers operated under decreasing returns to scale or above-optimal size. Consequently, unlike the hypothesis, it is found that half of the farmers were experiencing either increasing or decreasing returns to scale. Therefore, the hypothesis which claimed that smallholder farmers operate under constant returns to scale was rejected.

The two-limit Tobit regression model revealed that while family size, farming experience, walking distance to the nearest main market, credit access and total land cultivated during the long rainy season affect technical inefficiency positively and significantly; age of household head was found to have a negative and significant influence on technical inefficiency. The model further showed that economic inefficiency was positively and significantly affected by family size, farming experience and membership to associations and coops. But presence of a role (responsibility) of the household head in the community contributed negatively and significantly to economic inefficiency. However, significant effect was not found for sex and education level of the household head, plot distance from residence and number of contacts with government extension agents on technical or economic inefficiency.

Moreover, the study established that family size and farming experience were double effect variables that simultaneously and significantly affect technical and economic inefficiency; thus prioritized as the most critical factors determining resource use inefficiency in the study areas. Therefore, unlike the hypothesis, it is concluded that except family size and farming experience other factors were found either insignificant or significant but single effect.

5.2 Policy Implications

A policymaker's interest may lie both on knowing how far a given farm can increase its output, without using further resources, and also identification of important policy variables for action. Therefore, based on the findings of this study, policy implications are made to enhance resource use efficiency and increase crop productivity in the central highlands of Ethiopia.

The DEA results on returns to scale revealed that about 37 percent of the smallholder farmers operate under decreasing returns to scale or supra optimal (above optimal) size of inputs. Therefore, it has a policy implication that continuous training and field follow up of smallholder farmers about recommended rate of input uses during pre-harvesting agricultural activities should be given. This will substantially help smallholder farmers to survive and exploit opportunities in the competitive market. Moreover, traditional contractual agreements should be backed up by formal laws so as to facilitate and encourage the redistribution of land among producers.

Larger family size positively contributes to technical inefficiency. This implies that government should deliver family planning programs to reduce the size of emerging households and hence control population increment in the long-run. Such policy action will reduce the population pressure on the environment and natural resources that lead to degradation and marginality of agricultural lands hence low productivity. The variable family size is also important policy variable in that the change in family size has double effects as it affects both technical and economic inefficiency positively and significantly.

The study has shown that farmers having access to credit are more technically inefficient than those with no access to credit services. This means that there should be access to credit services for smallholder farmers at reasonable market interest rate, on time and in the needed amount to help farmers acquire inputs. This should be combined with continued availability of complementary agricultural support services, including extension and training. As a result, it would facilitate transfer and adoption of technologies by farmers that leads to improvement in productivity and efficiency.

Farming experience was also found to be as one of the most important double effect policy variable in efficiency and productivity enhancement. The result implies that there should be policies that encourage experienced farmers to shift from traditional to modern production technologies. This can be achieved via easy access to modern inputs, awareness creation about modern technologies and improved crop varieties; experience sharing between adopters and non adopters in continues basis.

Furthermore, the study findings indicated that the smallholder farmers located closer to the market are technically more efficient than those located far from the market. It, therefore, implies for policy makers that there should be a focus on development of market and road infrastructure so as to facilitate market participation and integration of far distant resident smallholder farmers. As a result, development will also be achieved on the margin where market accesses were constraints.

Larger size of land cultivated was found to affect technical inefficiency positively and significantly. This may be perhaps farmers who cultivate a larger area of land using a traditional way of production might not be able to carry out important agricultural operations timely. Moreover, modern technologies may not be applied as recommended rate given financial constraints when land size is large. For policy makers, it implies that a land policy that supports the redistribution of land or improves access to inputs increases efficiency of smallholder farmers. In turn, it increases production and productivity that reduces encroachment of smallholder farmers to the marginal areas, forest and woodlands due to decline in productivity of their land.

Moreover, age should be considered in increasing resource use efficiency and agricultural productivity. This is because results showed that younger farmers are technically more inefficient than older ones. It implies that there should be policies to improve resource use efficiency of younger farmers and encourage them to be in farming activities by providing them incentives. Continues trainings on the agricultural business environment and follow up during agricultural operation for younger farmers should be provided. However, this should not be at the expense of older ones.

Membership to farmers associations was found to affect economic inefficiency positively and significantly. It is established that associations in the study areas are not effective in reducing economic inefficiency of member farmers. Therefore, it implies that there should be clear and agricultural oriented missions for associations. Moreover, there must be active participation of farmers through giving leadership especially the marginalized people including women that help member farmers to increase their resource use efficiency.

Presence of a role of household head in the community was found to negatively affect economic inefficiency in crops production. Therefore, it implies that community-based and people-led agricultural activities and projects should be established to increase accountability and hence resource use efficiency and productivity of smallholder farmers. Community based resource management also avoids environmental degradation and marginality of agricultural lands. Thus, policies that are empowering the community and community-based programs should be pursued.

6. REFERENCES

Admassie, A. and Heidhues, F. (1996), Estimation of Technical Efficiency of Smallholder Farmers in Central Highlands of Ethiopia. *Ethiopian Journal of Agricultural Economics* 1(1):19-35.

Admasu, A. and Paul, I. (2010). Assessment on the Mechanisms and Challenges of Small scale Agricultural Credit from Commercial Banks in Ethiopia: The case of Ada'a liben Woreda Ethiopia. *Journal of Sustainable Development in Africa 12(3): pp.* 20.

Agrawal, A. (2001). State Formation in Community Spaces? Decentralization of Control over Forests in the Kumaon Himalaya, India. *Journal of Asian Studies* 60 (1): 9-41.

Ahmed, S. (2001). Empowering Rural Women? Policies, Institutions, and Gendered Outcomes in Natural Resources Management. *Development in Practice* 11 (4): 535-537.

Aigner, D.J., Lovell, C.A. and Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics* 6:21-37.

Ajibefun, I.A. (2002). Analysis of Policy Issues in the Technical Efficiency of Small Scale Farmers Using the Stochastic Frontier Production: With Application to Nigerian Farmers. Paper Prepared for Presentation at the International Farm Management Association Congress, Wageningen, The Netherlands.

Alema, D., Beers, G., Groot, N. and Jager, A. (undated). Concept Note: Agriculture Policy Support Ethiopia, Ethiopia. http://www.wageningenuniversity.nl/NR/rdonlyres/655D8A6E-FB2C-4523-93BD- F116D18E6AE0/95693/ConceptNote6PolicySupport_160609_.pdf

Alemdar, T. and Ören, M.N. (2006). Determinants of Technical Efficiency of Wheat Farming in Southeastern Anatolina, Turkey: A Non Parametric Technical Efficiency Analysis. *Journal of Applied sciences* 6(4):827-830.

Alemu, B.A., Nuppenau, E.A. and Bolland, H. (2009). Technical Efficiency across Agro-ecological Zones in East Gojjam, Ethiopia: The impact of Poverty and Asset Endowments. *Agricultural Journal* 4(4): 202-207.

Field Cod

Alene, A.D. and Hassan, R.M. (2002). Measuring the Impact of Ethiopia's New Extension Program on the Productive Efficiency of Farmers, Contributed Paper Selected for Presentation of the 25th International Conference of Agricultural Economics, August 16 – 22, South Africa.

Ali, M. (1996). Quantifying the Socio–economic Determinants of Sustainable Crop Production. *Agricultural Economics* 14(1): 45–60.

Ali, M. and Flinn, J.C. (1989). Profit Efficiency among Basmati Rice Producers in Pakistan, Punjab. *American Journal of Agricultural Economics* 71:303-310.

Amemiya, T. (1984). Tobit model: A Survey. *Journal of Econometrica*. 24:3-63.

Amemiya, T. (1985). *Advanced Econometrics*, Harvard University press, Cambridge, Massachusetts.

Anage, A. (undated). Increasing Finance for Sustainable Land Management: Ethiopia. The Global Mechanism of the United Nations Convention to Combat Desertification. Environmental Protection Authority, Addis Ababa, Ethiopia. Also available at http://global-mechanism.org/about-us/kb/country-factsheets

Andreu, M.L. (2008). Studies on the Economic Efficiency of Kansas Farms. An Abstract of unpublished PHD Dissertation, Kansas State University, Manhattan, Kansas.

Arabmazar, A. and Schmidt, P. (1981). Further evidence on the robustness of the tobit estimator to hetroscedasticity. *Journal of Econometrics* 17(2): 253-258.

Arabmazar, A. and Schmidt, P. (1982). An investigation into the Robustness of the Tobit Estimator to Nonnormality. *Econometrica*, 50 (4): 1055-1063.

Asfaw, G. (2003). Breaking the Cycle of Recurrent Famine in Ethiopia. In Mengistu, S. and De Stoop, C. (eds) Proceedings of the First Green Forum Conference held in Addis Ababa, 2-4 October 2006, on Environment for Survival-Taking Stock of Ethiopia's Environment. Green Forum Conference Proceedings No. 1.

Asselin, L. (2003). Module 6 CBMS as a Tool for Impact Assessment of PRSP. *CBMS Methodology*. CBMS MIMAP International Workshop, Hanoi, January 6-10 2003. Pp.86.

Awulachew, S. B. (undated). Improved Agricultural Water Management: Assessment of Constraints and Opportunities for Agricultural Development in Ethiopia. International Water Management Institute (IWMI).

Ayele, Z. E. (2008). Smallholder Farmers' Decision Making in Farm Tree Growing in the Highlands of Ethiopia. Unpublished Doctoral Dissertation, Oregon State University, USA

Bakhsh, K. (2007). An Analysis of Technical Efficiency and Profitability of growing Potato, Carrot, Radish and Bitter Gourd: A case study of Pakistani Punjab. Unpublished Ph.D Dissertation, Department of Farm Management, University of Agriculture, Faisalabad, Pakistan.

Banker, R.D. and Thrall, R.M. (1992). Estimation of Returns to scale using Data Envelopment Analysis. *European Journal of Operational Research* 62: 74-84.

Banker, R.D., Charnes, A. and Cooper, W.W. (1984). Some Models of Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Journal of Management Science* 30: 1078 – 1092.

Barros, C.P. and Mascarenhas, M.J. (2005). Technical and Allocative Efficiency in a Chain of Small Hotels. *International Journal of Hospitality Management* 24(3): 415-36.

Battese, G.E., Milak, S.J. and Gill, M.A. (1996). An Investigation of Technical Inefficiency of Production of Wheat Farmers in Four Districts of Pakistan. *Journal of Agricultural Economics* 47 (1): 37-49.

Bayou, D. (1999). Technical Efficiency and Soil Conservation: Estimation of Stochastic Frontier Production Function Using Panel Data from the Philippine Land Frontier, Department of Agricultural and Applied Economics, University of Wisconsin, Madison.

Bejiga, G., Eshete, M. and Anbessa, Y. (1996). Improved Cultivars and Production Technology of Chickpea in Ethiopia. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia. In: Shiferaw, B. and Teklewold, H. (2007). Structure and Functioning of Chickpea

Markets in Ethiopia: Evidence based on analyses of Value Chains Linking Smallholders and Markets. Improving Productivity and Market Success (IPMS) of Ethiopian Farmers Project Working Paper 6. ILRI (International Livestock Research Institute), Nairobi, Kenya. pp. 63.

Birega, G. (undated). Preliminary Country paper of Ethiopia on competition regime: Capacity building on competition policy in select countries of Eastern and Southern Africa. 7UP 3 Project. *AHa Ethiopian Consumer Protection Association* (AHa ECoPA). Pp. 21.

Bishaw, B. (1993). Determining Options for Agroforestry Systems for the Rehabilitation of Degraded Watersheds in Alemaya Basin, Hararghe Highlands, Ethiopia. Ph.D. dissertation, Oregon State University.

Bishaw, B. (2009). Deforestation and Land Degradation in the Ethiopian Highlands: A Strategy for Physical Recovery. *Ethiopian e-Journal for Research and Innovation Foresight* 1 (1): Inaugural Issue: 5-18.

Blaikie, N. (2003). *Analyzing Quantitative Data: From Description to Explanation.* Sage Publications, London.

Bogale, T. and Bogale, A. (2005). Technical Efficiency of Resource Use in the Production of Irrigated Potato: A Study of Farmers Using Modern and Traditional Irrigation Schemes in Awi Zone,E thiopia. *Journal of Agriculture and Rural Development in the Tropics and Subtropics 106*(1): 59–70.

Brown, C. C. and Moffitt, R. (1982). The effect of ignoring Heteroscedasticity on Estimates of the Tobit Model. Mimeo, University of Maryland, department of Economics.

Bruch, S.K., Ferree, M.M. and Soss, J. (2009). From Policy to Polity: Democracy, Paternalism, and the Incorporation of Disadvantaged Citizens. Institute for Research on Poverty. Discussion Paper no. 1362-09.

Chanyalew, D., Adenew, B. and Mellor, J. (2010). Ethiopia’s Agricultural Sector Policy and Investment Framework (PIF) (2010-2020), Draft Final Report. Federal Democratic Republic of Ethiopia, Ministry of Agriculture and Rural Development.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978). Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research* 2: 429-444.

Chatterjee, S., and Price, B. (1991). *Regression Analysis by Example (2nd Ed.)*. New York: Wiley.

Chirwa, E.W. (2007). Sources of Technical Efficiency among Smallholder Maize Farmers in Southern Malawi. *African Economic Research Consortium, Research Paper 172*. pp. 21.

Coelli, T.J. (1996). A Guide to DEAP version 2.1: A Data Envelopment Analysis (computer) Program. CEPA working paper No. 8/96. *Center for Efficiency and Productivity Analysis,* University of New England.

Coelli, T.J. (1996). A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation. CEPA Working Paper No. 07/96. *Center for Efficiency and Productivity Analysis,* University of New England, Armidale.

Coelli, T.J. (1996a). Specification and Estimation of Stochastic Frontier Production Functions. Unpublished Ph.D. Dissertation, University of New England, Australia

Coelli, T.J. and Prasada Rao, D.S. (2003). Total Factor Productivity Growth in Agriculture: A Malmquist Index Analysis of 93 Countries 1980-2000. In Proceedings of the 25th International Conference of Agricultural Economists. *Reshaping Agricultural Contribution to Society*. pp. 115-134.

Coelli, T.J., Prasada Rao, D.S. and Battese, G.E. (1998). An Introduction to Efficiency and Productivity Analysis. Kluwer Academic Publishers, London.

Coelli, T.J., Prasada Rao, D.S., O'Donnell, C.J. and Battese, G.E. (2005). *An Introduction to Efficiency and Productivity Analysis (2nd Edition)*. Springer Science +Bussiness Media Inc.

Constable, M. (1985). Ethiopian Highland Reclamation study. Working Paper 24. Addis Ababa, Ethiopia. In: Bishaw, B. (1993). Determining Options for Agroforestry Systems for the Rehabilitation of Degraded Watersheds in Alemaya Basin, Hararghe Highlands, Ethiopia. Ph.D. dissertation, Oregon State University.

Cooper, W.W., Seiford, L.M. and Tone, K. (2000). *Data Envelopment Analysis: A Comprehensive text with Models, Applications, References, and DEA-solver software*. Kluwer Academic Publishers, USA.

Cooper, W.W., Seiford, L.M. and Tone, K. (2007). *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software (2nd Ed.)*. New York: Springer Science + Business Media.

Cooper, W.W., Seiford, L.M. and Zhu, J. (2004). Data Envelopment Analysis: History, Models and Interpretations. *Handbook on Data Envelopment Analysis*. pp. 1-39.

Dixon, J., Taniguchi, K., Wattenbach, W. and Tanyeri-Arbur, A. (2004). *Smallholders, globalization and policy analysis*. Rome, FAO, AGSF. Occasional Paper 5, also available at http://www.fao.org/docrep/007/y5784e/y5784e00.htm#Contents

Dudu, H. (2006). Efficiency in Turkish Agriculture: A Farm Household Level Analysis. Unpublished Thesis, Middle East Technical University.

Ekayanake, S.A. (1987). Location Specificity, Settler type and Productive Efficiency: A study of the Mahaweli Project in Sri Lanka. *Journal of Development Studies*. 23 (4):509-521.

FAO and IFA (1999). Food and Agriculture Organization of the United Nations and International Fertilizer Industry Association. *Fertilizer Strategies*. FAO, Rome.

Farrell, M.J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society* 120 (3): 253 – 290.

Ferrier, G.D. and Lovell, C.A. (1990). Measuring cost efficiency in Banking: Econometric and Linear Programming Evidence. *Journal of Econometrics* 46: 229-245.

Fried, H.O., Lovell, C.A. and Schmidt, S.S. (2008). *The Measurement of Productive Efficiency and Productivity Growth.* Oxford University Press Inc., New York.

Galagedera, D.U.A. and Silvapulle, P. (2000). Australian Mutual Fund Performance Appraisal using Data Envelopment Analysis. 13th Australasian Finance & Banking Conference, Sydney, Australia.

Gebeyehu, L. (2010). *Organic Agriculture Sector Development in Ethiopia.* A paper Presented at East African Organic Conference, Safari Park Hotel, Nairobi, Kenya. Pp.4.

Gebreegziabher, Z., Oskam, A. and Woldehanna, T. (2005). Technical Efficiency of Peasant Farmers in Northern Ethiopia: A Stochastic Frontier Approach.

Gebremedhin, B., Hoekstra, D. and Tegegne, A. (2006). *Commercialization of Ethiopian agriculture: Extension service from input supplier to knowledge broker and facilitator.* IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 1. ILRI (International Livestock Research Institute), Nairobi, Kenya. 36 pp.

Getu, H. (1997). Analysis of Performance Variation: The Case of Smallholder Farms in Eastern Hararghe Region. Unpublished M.Sc Thesis, Alemaya University.

Ghorbani, A., Mirmahdavi, S.A. and Rahimabadi, E. (2009). Economic efficiency of Caspian Cattle Feedlot Farms. *Asian Journal of Animal Sciences* 3(1): 25-32.

Ghura, D. and Just, R.E. (1992). Education, infrastructure and instability in East African Agriculture: Implications for Structural Adjustment Programs. *Finance and Economic Development*. 1:85–105.

Goibov, M., Schmitz, P.M. and Alemu, B.A. (2010). Technical Efficiency of Cash and Food Crops Producing Farms across Three Districts in Northern Tajikistan: a Non-parametric Approach. *Australian Journal of Basic and Applied Sciences* 4(11): 5705-5716.

Goodwin, B.K. (1992). An analysis of factors associated with consumers' use of grocery coupons. *Journal of Agricultural and Resource Economics* 17:110-120.

Greene, W.H. (2003). *Econometric Analysis* (5th ed.). Pearson Education, Inc. Upper saddle river, New Jersey.

Hailu, G.., Goddard, E.W. and Jeffrey S.R. (2005). Measuring Efficiency in Fruit and Vegetable Marketing Co-operatives with Heterogeneous Technologies in Canada. Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, Haji, J. (2006). Production Efficiency of Smallholder's Vegetable Dominated mixed farming system in Eastern Ethiopia: A non-parametric approach. *Journal of African Economies* 16:1-27.

Haji, J. (2008). Economic Efficiency and Marketing Performance of Vegetable Production in the Eastern and Central Parts of Ethiopia. Unpublished Doctoral Thesis, Swedish University of Agricultural Sciences.

Hoekstra, D., Torquebiau, E. and Bishaw, B. (1990). Agroforestry: Potentials and Research Needs for the Ethiopian Highlands. No. 21. ICRAF, Nairobi, Kenya. 115 p. In: Bishaw, B. (1993). Determining Options for Agroforestry Systems for the Rehabilitation of Degraded Watersheds in Alemaya Basin, Hararghe Highlands, Ethiopia. Ph.D. dissertation, Oregon State University.

Hurd, M. (1979). Estimation in Truncated Samples when there is Hetroscedasticity. *Journal of Econometrics* 11 (2-3): 247-258.

Idiong, I.C. (2007). Estimation of farm level technical efficiency in small scale swamp rice production in Cross River State of Nigeria: A Stochastic Frontier Approach. *World Journal of Agricultural Sciences* 3: 653-658.

International Food Policy Research Institute (IFPRI) (2009). Implications of Accelerated Agricultural Growth in Ethiopia. Ethiopia Strategy Support Program II (ESSP - II) (Brief No. 2). Pp. 2.

International Fund for Agricultural Development (IFAD) (2009). Federal Democratic Republic of Ethiopia. Country Programme Evaluation, Report No. 2045-ET

International Livestock Center for Africa (ILCA) (1983). Research on Farm and Livestock Productivity in the Central Ethiopian Highlands: Initial results, 1977-1980. *ILCA research report* (4), Addis Ababa, Ethiopia.

Jabbar, M.A., Peden, D. G., Mohamed- Saleem, M. A. and Li Pun, H. (2000). Agro-ecosystems, Natural Resources Management and Human Health Related Research in East Africa.

Proceedings of an IDRC–ILRI International Workshop held at ILRI,Addis Ababa, Ethiopia, 11–15 May 1998. ILRI (International Livestock Research Institute), Nairobi, Kenya. Pp. 254.

Javed, M.I. (2009). Efficiency Analysis of Cotton-Wheat and Rice-Wheat Systems in Punjab, Pakistan. Unpublished Doctoral Thesis, University of Agriculture, Faisalabad.

Jenkinson, C. (1998). Measuring Health Status and Quality of Life. Question Bank Topic Commentary on Health.

Jondraw, J., Lovell, C.A., Materov, I.S. and Schmidt, P. (1982). On Estimation of Technical Inefficiency in Stochastic Frontier Production Function Model. *Journal of Econometrics* 19: 233 – 238.

Kalirajan, K.P. and Shand, R.T. (1988). Firm and Product-Specific Technical Efficiencies in a Multiple Product Cycle System. *Journal of Development Studies* 25: 83–96.

Kassie, M. and Holden, S. (2007). Sharecropping Efficiency in Ethiopia: Threats of Eviction and Kinship. *Agricultural Economics* 37:179-188.

Khairo, S.A. and Battese, G.E. (2004). A Study of Technical Inefficiencies of Maize Farmers within and outside the New Agricultural Extension Program in the Harari Region of Ethiopia.

Kothari, C.K. (2004). *Research Methodology: Methods and Techniques (2nd Rev. Ed).* New Age International Publishers, New Delhi, India.

Krasachat, W. (2009). Technical Efficiency of Shrimp Farms in Thailand under Good Agricultural Practice System. A contributed paper for Tropentag 2009 Conference on International Research on Food Security, Natural Resource Management and Rural Development. pp. 4.

Kumar, S. and, Gulati, R. (2008). An Examination of Technical, Pure Technical, and Scale Efficiencies in Indian Public Sector Banks using Data Envelopment Analysis. *Eurasian Journal of Business and Economics* 1 (2): 33-69.

Kumbhakar, S.C. and Tsionas, E.G. (2006). Estimation of Stochastic Production Functions with Input-Oriented Technical Efficiency. *Journal of Econometrics* 133(1): 71-96.

Kuosmanen, T. (2002). Modeling blank data entries in data envelopment analysis, EconWPA working paper No. 0210001 (Econometrics), Available online at: http://ideas.repec.org/p/wpa/ wuwpem/0210001.html.

Llewelyn, R.V. and Williams, J.R. (1996). Nonparametric Analysis of Technical, Pure Technical and Scale Efficiencies for Food Crop Production in East Java, Indonesia. *Journal of Agricultural Economics* 15 (2): 113 - 126.

Long, J.S. (1997). *Regression Models for Categorical and Limited Dependent Variables*. Advanced Quantitative Techniques in the Social sciences Series (7). Sage Publications. California, USA.

Maddala, G.S. (1983). *Limited Dependent and Qualitative Variables in Econometrics*. New York: Cambridge University press.

Maddala, G.S. (1985). *Limited Dependent and Qualitative Variables in Econometrics*. Cambridge University Press, Cambridge.

Maddala, G.S. and Nelson, F.D. (1975). Specification Errors in Limited Dependent Variable Models, working paper No. 96. *National Bureau of Economic Research* Cambridge Mass.

Mbaga, M.D., Romain R, Larue, B. and Lebel, L. (2003). Assessing Technical Efficiency of Quebec Dairy Farms. *Canadian Journal of Agricultural Economics* 51: 121 – 137.

McDonald, J.F. and Moffitt, R.A. (1980).The use of Tobit Analysis. The *Review of Econometrics and Statistics* 62 (2):318-321.

Medhin, H. and Köhlin, G. (2008). Soil conservation and small-scale food production in Highland Ethiopia: A stochastic meta-frontier approach. *Environment for Development*, Discussion Paper Series EfD DP 08-22. Pp. 34.

Meeunsen, W. and Van den Broeck, J. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with composed error. *International Economics Review* 18: 435- 444.

Mengistu, S. and De Stoop, C. (2007). Environment for Survival – Taking Stock of Ethiopia's Environment. Proceedings of the First Green Forum Conference held in Addis Ababa, 2-4 October, 2006, *Green Forum Conference Proceedings No. 1.*

Mersha, F.G. (2004). Analysis of Technical Efficiency of Wheat Production: A Study in Machakel *Woreda*, Ethiopia. Unpublished MSc Thesis, Alemaya University.

Ministry of Agriculture and Rural Development (MoARD) (2004). Market–orientated Development Master Plan of the Ministry of Agriculture and Rural Development of the Federal Democratic Republic of Ethiopia.

Mohammad, H., Farah, H., Mwangi, W. and Belay, K.(1999). Factors Influencing Technical Efficiency of Crop Production in Assassa District of Southern Ethiopia. Unpublished M.Sc. Thesis. Alemaya University.

Mohanty, R. (2004). Institutional Dynamics and Participatory Spaces: The Making and Unmaking of Participation in Local Forest Management in India. *IDS Bulletin* 35 (2): 26-32.

Nossal, K. and Gooday, P. (2009). Raising productivity growth in Australian agriculture. abare.gov.au *issue, insights 09.7.*

Nyagaka, D.O., Obare, G.A., Omiti, J.M. and Nguyo, W. (2010). Technical Efficiency in Resource Use: Evidence from Smallholder Irish Potato Farmers in Nyandarua North District, Kenya. *African Journal of Agricultural Research* 5(11):1179-1186.

Nyssen, J., Naudts, J. De Geyndt, K. Haile, M., Poesen, J., Moeyersons, J. and Decker, J. (2008). Soils and Land Use in the Tigray Highlands (Northern Ethiopia). *Land Degrad. Develop. 19: 257–274.*

O'Neill, S., Leavy, A. and Matthews, A. (2001). Measuring productivity change and efficiency on Irish farms. Technical report, Teagasc Rural Economy Centre.

Ogundari, K. and Ojo, S.O. (2006). An Examination of Technical, Economic and Allocative Efficiency of small farms: The case study of Cassava Farmers in Osun State of Nigeria. *Journal of Central European Agriculture* 7:423-432.

Okoruwa, V.O., Ogundele, O.O. and Oyewusi, D.O. (2006). Efficiency and Productivity of Farmers in Naigeria: A Poster paper prepared for presentation at the International Association of Agricultural Economists Conference Gold Coast, Australia, August 12- 18.

Okoye, B.C., Onyenweaku, C.E. and Asumugha, G.N. (2007). Economic Efficiency of Smallholder Cocoyam Farmers in Anambra State, Nigeria: a Translog Stochastic Frontier Cost Function Approach. Munich Personal RePEc Archive (MPRA). Online at http://mpra.ub.uni-muenchen.de/16284/. MPRA Paper No. 16284, pp. 11.

Olowa, O. W. and Olowa, O. A. (2010). Sources of Technical Efficiency among Smallholder Maize Farmers in Osun State of Nigeria. *Research Journal of Applied Sciences* 5(2): 115-122.

Omonona, B.T., Egbetokun, O.A. and Akanbi, A.T. (2010). Farmers Resource – Use and Technical Efficiency in Cowpea Production in Nigeria. *Economic Analysis and Policy* 40 (1): 87-95.

Ozkan, B., Ceylan, R.F and Kizilay, H. (2009). A Review of Literature on Productive Efficiency in Agricultural Production. *Journal of Applied Sciences Research* 5(7): 796-801.

Parikh, A. and Shan, K. (1994). Measurement of Technical Efficiency in North-West Frontier Province of Pakistan. *Journal of Agricultural Economics* 45 (1):132-138.

Pedraja-Chaparro, F., Salinas-Jimenez, J. and Smith, P. (1999). On the quality of the Data Envelopment Analysis Model. *Journal of Operational Research Science* 50: 636-644.

Pender, J., Hazell, P.B.R. and Garrett, J.L. (2001). Reducing poverty and protecting the environment: The Overlooked Potential of Less-Favored Lands. In: Pinstrup-Andersen, P. and Pandya-Lorch, R. eds, *The Unfinished Agenda: Perspectives on overcoming hunger, poverty and environmental degradation*, IFPRI, Washington, DC.

Peter, K. (1998). *A Guide to Econometrics (5th ed.).* Cambridge, MIT Press.

Pinckney, C. (1993). Is market liberalization compatible with food security? Food Policy,18(4): 325–33. In : Tchale, H. (2009). The efficiency of smallholder agriculture in Malawi. World Bank, Lilongwe, Malawi. *AFJARE* 3 (2): 101-121.

Field Cod

Quisumbing, A.R. (1995). Gender Differences in Agricultural Productivity: A Survey of Empirical Evidence. Food Consumption and Nutrition Division, IFPRI, FCND Discussion Paper No. 5.

Rabe-Hesketh, S. and Everitt, B. (2000). *A Handbook of Statistical Analyses using STATA* (2nd Ed.). Chapman and Hall/CRC

Raju, K.S. and Kumar, D.N. (2006). Ranking Irrigation Planning Alternatives using Data Envelopment Analysis. *Water Resources Management* 20:553-566.

Rezitis, A.N., Tsiboukas, K. and Tsoukalas, S. (2002). Measuring technical efficiency in the Greek agricultural sector. *Applied Economics* 34: 1345–1357.

Ruggiero, J. (1998). A New Approach for Technical Efficiency Estimation in Multiple Output Production. *European Journal of Operational Research* 111: 369-380.

Sayer, J. and Campbell, B. (2004). *The Science of Sustainable Development: Local livelihoods and the global environment*. Cambridge University Press, Cambridge.

Seyoum, E.T., Battese, G.E. and. Fleming, E.M. (1998). Technical Efficiency and Productivity of Maize Producers in Eastern Ethiopia: A Study of Farmers within and Outside the Sasakawa – Global 2000 Project. *Journal of Agricultural Economics* 19: 341 – 348.

Shiferaw, B. and Teklewold, H. (2007). Structure and Functioning of Chickpea Markets in Ethiopia: Evidence based on analyses of Value Chains Linking Smallholders and Markets. Improving Productivity and Market Success (IPMS) of Ethiopian Farmers Project Working Paper 6. ILRI (International Livestock Research Institute), Nairobi, Kenya. pp. 63.

Sigelman, L. and Zeng, L. (1999). Analyzing Censored and Sample-Selected Data with Tobit and Heckit Models. *Political Analysis* 8:167–182.

Singh, K. (2007). *Quantitative Social Research Methods*. Sage Publications, New Delhi, India.

Smith, P. (1997). Model Misspecification in data envelopment analysis. *Annals of Operations Research* 73: 233-252.

Tchale, H. (2009). The efficiency of smallholder agriculture in Malawi. World Bank, Lilongwe, Malawi. *AFJARE* 3 (2): 101-121.

Tesfay, G., Ruben, R., Pender, J. and Kuyvenhoven, A. (2005). Resource Use Efficiency on own and Sharecropped Plots in Northern Ethiopia: determinants and implications for sustainability.

Tewodros, A. (2009). Overview of Achievements and Challenges in Implementing CDD Projects in Pastoral Communities: The Case of Pastoral Community Development Project in Ethiopia. Presented at International Conference on CDD and Rural Poverty Alleviation October 18-19, 2009, Beijing, China.

Thompson, R.G., Dharmapala, P.S., and Thrall, R.M. (1993). Importance for DEA of zeros in data, multipliers and solutions. *Journal of Productivity Analysis 4(4):* 379–390.

Tran, N.A., Shively, G., and Preckel, P. (2008). A New Method for detecting Outliers in Data Envelopment Analysis. *Applied Economics Letters* 1–4, iFirst

Udoh, E.J. (2000). Land Management and Resource-Use Efficiency among Farmers in South Eastern Nigeria. Unpublished Doctoral Thesis, University of Ibadan.

Umoh G. S. (2006). Resource Use Efficiency in Urban Farming: An Application of Stochastic Frontier Production Function. *International Journal of Agriculture and Biology 8 (1):* 38–44.

UN Millennium Project (2005). *Investing in development: A Practical Plan to Achieve the Millennium Development Goals. Overview.*

United States Central Intelligence Agency (CIA) (2007). World Fact Book, Ethiopian Economy 2007. http://www.allcountries.org/wfb2007/ethiopia/ethiopia_economy.html.

Upadhyaya, H.K., David, C.C., Thapa, G.B., and Otsuka, K. (1993). Adoption and Productivity Impact of Modern Rice Varieties in Nepal. *The Developing Economies* 31:122-137.

Van Passel, S., Lauwers, L. and Van Huylenbroeck, G. (undated). *Factors of farm performance: an empirical analysis of structural and managerial characteristics*.

Wang, J., Wailes, E.J. and Cramer, G.L. (1996). A Shadow-Price Frontier Measurement of Profit Efficiency in Chinese Agriculture. *American Journal of Agricultural Economics* 78(1): 146-156.

Wooldridge, J.M. (2002). *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MIT Press.

World Bank (2003). Reaching the Rural Poor: A renewed strategy for Rural Development, World Bank, Washington, DC.

Yilmaz, B. and Harmancioğlu, N.B. (2008). The use of Data Envelopment Analysis in Assessment of Irrigation Efficiency. *International Congress on River Basin Management, Basin Water Management. pp.*346-357.

7. APPENDICES

(A): SURVEY QUESTIONNAIRE

STUDY TITLE: **ECONOMIC EFFICIENCY OF SMALLHOLDER MAJOR CROPS PRODUCTION IN THE CENTRAL HIGHLANDS OF ETHIOPIA**

CONFIDENTIALITY: This questionnaire is being administered for the academic purpose. The information will be used to evaluate the farm level economic efficiency and the underlying determinants in smallholder major crops production in the central highlands of Ethiopia.

Date of interview: Day:……………Month…………………………Year:...................................

Interviewed by:..

Date checked: Day: ………………...Month:……………………Year:...................................

Checked by: ....

1.0 FARMER AND SITE IDENTIFICATION

1.1 Farmer (respondent) name…………………………………………………………………..

1.2 (2a) District……………............................. (2 b) *Kebele*…………………………………..

1.3 Number of years stayed in the village (kebele)………………………………………………

1.4 Experience in growing Chickpea since formed a family (years): …………………………..

1.5 Household distance to farmers' cooperative (km)…..……………………………………..

1.6 Household residence distance to extension agent office (km)…………….. …………….

1.7 Household distance to the nearest market place (km)………………………………….. .

1.8 Any responsibility in the *kebele* (community) (including official roles)… 1. Yes 0. No

2.0 MEMBERSHIP TO FARMER ASSOCIATIONS IN THE LAST 2 YEARS

Type of institutions (Association, Coop , Group or Local Admin) household has been a member (codes A)	Association or group functions (Codes B) Rank 3	Year joined	Role in the institution (codes C)	Still a member now (Codes D)
1	**2**	**3**	**4**	**5**

Codes A
1. Input Supply/service coops /union
2. crop/seed producer and marketing group/coops
3. Local administration *(Kebele)*
4. Farmers' Association
5. Women's Association
6. Youth Association
7. Church/mosque Association/congregation
8. Saving and credit group
9. Funeral association (*Idir)*
10. Government team
11. Water User's Association
12. Other, specify…….

Codes B
1. Produce marketing
2. Input access/marketing
3. Seed production
4. Farmer research group
5. Savings and credit (Ekuub)
6. Funeral group (Edir)
7. Tree planting and nurseries
8. Soil & water conservation
9. Church group/congregation
10. Input credit
11. Other, specify…

Codes C
1. Elected official
2. Ordinary member
4. Agricultural Cadre
5. Model or contact farmer
6. Messenger
7. Cashier
8. Coordinator
9. Secretary
10. Militia
11. Store keeper
12. Executive committee member
13. Other specify………

Codes D
1. Yes
0. No

3.0 HOUSEHOLD COMPOSITION AND CHARACTERISTICS

Name of Household Member	Gender Codes A	Age (years)	Household head Education level (years) Codes B
1.			
2.			
3.			

Codes:

Codes A	**Codes B**
1. Male	0. None (illiterate)
0. Female	1. Adult education or 1 year of education
	* Give other education in years

4.0 CHARACTERISTICS OF PRODUCTION PLOTS FOR MAJOR CROPS

Land specific location name	Crop grown (codes A)	Crop variety (codes B)	Land size (*kert*)	Land ownership (Codes C)	Plot distance to residence (km)
1.					

Codes A	**Codes B**	**Codes C**
1. Chickpea	1. Improved	1. Owned
2. Teff	0. Local	2. Rented in
3. wheat		3. Borrowed in

5.0 CROP PRODUCTION INPUTS, INPUT COSTS AND OUTPUTS FOR ALL CROPS

plot code (From Table 4.0; Column 1)	Fertilizer				Seed			Field chemical		Total Labour (person-days)								Production (kg)
	DAP		Urea		Own saved/gift (kg)	Bought		litres	Birr/litre	Hired labour (Birr)	Ploughing, harrowing & planting	Frequency of ploughing l	Frequency of weeding	Weeding (1^{st} and 2^{nd} etc)	Chemical application	Harvesting	Threshing/shelling	
	kg	Value (Birr)	kg	Value (Birr)		Amount (kg)	Birr/kg											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

6.0 NEED AND ACCESS TO CREDIT SERVICES

Purposes for borrowing	Needed credit **(codes A)**	If YES, did you get it **(codes A)**	If **Yes**, got amount needed at market rate of interest? **(codes A)**
1. Buying seeds			
2. Buying fertilizer			
3. Buy other agricultural inputs			
4. Farm equipment/implements			
5. Buying oxen for traction			
6. Buy other livestock			
7. Invest in irrigation			
8. Non-farm business			
9. Buying food			
10. Children's education			
11. Family Health/medical			
12. Rent in (fixed) land			
13. Social obligations			

Codes A: 1. Yes 0. No

Note: This Questionnaire is extracted from the main instrument developed and used by ICRISAT.

(B): Notes on Output, Input and Input Cost Aggregation for DEA model:

1. Fertilizer
   1.1. Amount of DAP for a DMU is the sum of total amount of DAP used for Chickpea, *Teff* and Wheat production in kilograms; and its total cost/value is the total amount of money in ETB spent on DAP;
   1.2. Amount of Urea for a DMU is the sum of total amount of Urea used for Chickpea, *Teff* and Wheat production in kilograms; and its total cost/value is the total amount of money in ETB spent on Urea;
2. Field Chemicals
   2.1. The total amount of Field chemicals including pesticides and weed killers of a DMU is computed as the amount of field chemicals used for Chickpea, *Teff* and Wheat plots; and Cost of Chemical was computed as the product of total Chemical used*80 birr (using the average market price of pesticides as 80 ETB per liter in the study areas)
3. Human Labor in Man/days
   3.1. Total labor used for a DMU = Family Labor + Hired Labor
   3.2. Cost of Labor= Total Labor Man/days* 20 ETB/Man/day (1 Man/day= 8 hours of work/day = 1 Working day) and the value of family labor was approximated by the existing wage rate in the nearest village. Thus, 20 Birr per person per day was used to compute the cost of labor both for family and hired ones).
   3.3. Total Man/days= (Frequency of Ploughing*6 Man/days/*kert*)+(Planting*1 Man/day/*kert*) + Freq. Weeding*6 Man/days/*kert*)+ Freq. Chemical Application* 1 Man/day/*kert*+ Harvesting *8 Man/days/*kert*+ Threshing* 8 Man/days/*kert* (Notes: 1 hectare = 4 *kert*) (Assumptions: one time ploughing, planting, weeding, chemical application, harvesting, and threshing require, on average 6, 1, 6, 1, 8 and 8 man/days/*kert*, respectively.)
4. Seed
   4.1. Total Seed in kilograms used for each crop= Own seed + Bought Seed
   4.2. Seed cost = Value of own seed + cost of seed bought (Based on the nearest main market prices, 450.8 ETB/ 100 kg, 213.50 ETB/ 100 kg and 415 ETB/100 kg was used for seed prices to compute the value of own seed of chickpea, *teff* and wheat, respectively.)

5. Land
    5.1. Total Land used by a DMU= Land allotted for Chickpea + land allotted for Wheat+ Land allotted for *Teff*
    5.2. Cost of land= total Land used * 650 ETB/*kert* (Given the rental value of good quality land 650 ETB per *kert*,