Efficiency of Agricultural Production

Technical Efficiency of Major crops In Ethiopia: Stochastic Frontier Model

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Summary

Production and productivity can be boosted either through increased use of inputs and/or improvement in technology or by improving the efficiency of producers or firms, given fixed level of inputs and technology. Even though agriculture stays the main stay of Ethiopian economy, level of agricultural productivity in general and crop productivity in particular is very low. Out of the total grain production in Ethiopia, cereals account for roughly 60 percent of rural employment and 80 percent of total cultivated land. However, Yield of cereals has been consistently well below world and even of least developing countries average yield, indicating poor productivity of the crops in the country. Given capital constraint in the country, it is difficult to adopt new technology to enhance productivity. Hence, working to improve production efficiency is best option on hand. As a result, there are a number of studies done on area of efficiency analysis in Ethiopia. However, the novelty of this study can be explained by three facts. First of all it has used national data, collected by International Food Policy Research Institute (IFPRI), with enough number of observations to do plot level analysis considering biological factors that determine inefficiency. Second, efficiency analysis is not based on a single crop rather on major crops in general as well as *teff*, wheat and maize independently. Last but not least, the study employed one stage approach in which both technical efficiency and factors of inefficiency are analyzed simultaneously. Therefore, this study was done to evaluate the efficiency and identify factors that explain the variation in inefficiency of crop production in Ethiopia.

This study principally used the 2009 Ethiopia Rural Household Survey (ERHS) which is collected by IFPRI. As far as analysis is concerned, both descriptive and econometric methods were used. Descriptive statistics (mean, percentage, range, etc.) is used to summarize the variables in the model and describe the study area. Econometric model, Stochastic Production Frontier model, is used to estimate the elasticity of production function, determine the determinants of inefficiency and estimate the level of efficiency. Given that we are considering a developing country setting where by the main concern is output shortfall rather than input over use, preference has been given to primal or output oriented approach of measuring efficiency.

In this study, effort was made to test the hypotheses before rushing to interpret the model outputs. First, the γ parameter estimates of all production functions were significant at 5% significance level, indicating Stochastic Frontier Production function is more appropriate than convectional production function or there is significant technical inefficiency variation among plots. The γ value of 0.636 for the major crops production function can be then interpreted as, 63% of the variation in output among plots is explained by technical inefficiency. Similarly, variation in out put due to technical inefficiency for *teff*, wheat and maize production were calculated to be 88.5, 45.5 and 77.8 percent respectively. The second step, following the existence of inefficiency, is to check if there exist one or more variables that could explain the variation in technical inefficiency. Log likelihood ratio was used to test the hypothesis. Accordingly, all calculated LL ratio values were greater than the critical value of LL ratio, with upper 5 % level of significance. Hence, the null hypotheses that determinant variables in the inefficiency effect model are simultaneously equal to zero are rejected. In other words, there exists at least one explanatory variable that explains the variation in the technical inefficiency among plots.

The ML estimate results shown that, all variables were found to be binding in the production of major crops, meaning that an increase in one of inputs will enhance output keeping everything constant. As far as *teff* production is concerned, only land was a significant variable that explains the variation in *teff* output among plots. Land, DAP and seed were found to have significant and positive effect in wheat production. According to result of this study, land and seed were major determinants of maize production in Ethiopia. Generally, all significant input variables were found to affect output positively, as expected. Moreover, the model output depicted that the mean level of TE for major crops, *Teff*, Wheat and Maize production was found to be 63.56, 67.26, 84.16 and 91.41 percent, respectively.

The inefficiency effect analysis shown that, age of the household head measured in years was found to be the determinant of technical inefficiency, of *teff* production and education was found to have negative and significant effect on major crops and wheat technical inefficiency (1% significance level). Knowledge about land policy was found to have significant and negative effect on technical inefficiency of wheat production (1% significance level). Similarly, participation in soil and water conservation activities was found to have negative

and significant effect on technical inefficiency of major crops and wheat production. In this study frequency of extension contact was found to have unexpected and strange result; the more frequently the farmers meet extension workers the more it competes their time to do agricultural activities. The result of this study also confirmed as rich farmers are relatively less inefficient than poor once, in major crops production, and fertile plots of wheat are significantly less inefficient than infertile once. Similarly, flat teff and maize plots are more efficient than otherwise. The other plot specific variable that was found to have negative and significant effect on technical inefficiency of major crop production was adoption of improved seed. The last but not least, variable that explains variation in inefficiency was found to be livestock ownership. Generally, results of this study confirmed that there is a room to enhance productivity by improving the efficiency of production, given same level of input and current technology.

Preface

First and for most, I would like to be grateful for the unconditional love and care of the Almighty God and his mother St. Virgin Merry throughout the study period.

I express my sincere gratitude to my advisor Professor Kjell Arne Brekke for his understanding, guidance and supervision. He was so helpful and welcoming since the first time I forward him a request to be my supervisor.

Special thanks for International Food Policy Research Institute (IFPRI) for providing me the data used in this study, free of cost. I am also very grateful to the Norwegian State Educational Loan Fund for financing my study through Quota Scheme scholarship.

I am greatly indebted to my family, especially mom, for their patience and support during my stay out of home. I feel so great to express my thanks to my beloved, Helen, for her unlimited love, care and encouragement all the time. Lastly, but in no sense the least, I am thankful to my friends who made my stay at University of Oslo a memorable and valuable experience. My special thanks go to Mebrhatu, Muleta, Ashebir, Mehari and Habtu.

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1 Introduction

In this part of the thesis, background of the study, objectives and research questions of the thesis are presented.

1.1 Background of the Study

For most developing countries, enhancing the total production and productivity is not an option rather it is a must and the first priority in their policies. Production and productivity can be basically boosted using two ways. The first method is through increased use of inputs and/or improvement in technology given some level of input. The other option of improving productivity is to enhance the efficiency of producers or firms, given fixed level of inputs and technology. This study is mainly concerned about the second option of increasing productivity. The measurement of efficiency has remained an area of important research, especially in developing countries, where resources are scanty and opportunities for developing by inventing or adopting better technologies are dwindling (Bedasa and Krishnamoorthy, 1997).

Ethiopia's ambitious five-year growth and transformation plan, which was started in 2010, aims to double grain production by 2015. The major grain crops grown in the country are *teff*[1], wheat, maize, barley, sorghum, and millet. Out of the total grain production, cereals account for roughly 60 percent of rural employment and 80 percent of total cultivated land (Abu and Quintin, 2013). Yield of cereals has been consistently well below world and even of least developing countries average yield, indicating poor productivity of the crops in the country. According to FAO (2011) the average cereal yield for the world and least developing countries were 37.08 qt/ha and 20.19 qt/ha, respectively, however, the average cereal yield in Ethiopia was limited to 17.60 qt/ha.

Significant share (98 percent) of Ethiopia's agricultural output comes from small-scale and subsistence farmers operating under traditional practices. This has limited total production

[1] Teff (scientific name is *Eragrostis_teff*) is staple small size local cereal originated from Ethiopia.

that would have been produced in the country if the productivity of the small scale farmers were enhanced either by improving their production efficiency or by using modern technologies or a combination of both. Even though, there has been an increase in the total production of major crops in the country in the past decade, this has been due to increases in area cultivated (Seyoum, Dorosh and Sinafikeh, 2011). However, given the current technological conditions and the existing pressures on the farm land, pushing the production area further is difficult in Ethiopia (ADB, 2010). Hence the increase in the production failed to satisfy the growing demand of cereals. As a result, cereal import requirement of the country by 2010 was about 1.16 million tonne of which 520,000 tonne were imported commercially (FAO and WFP, 2010).

Empirical researches (Geta, Bogale, Kassa and Eyasu, 2013; Wassie, 2012; Kaleab and Birhanu, 2011) done in different parts of the country prevailed as there is potential to increase the productivity and/or efficiency of crop production. A study done by Geta *et al.,* (2013) in the southern part of Ethiopia, shows as there was 60 percent inefficiency in maize production. The average Technical Efficiency (TE) of small scale wheat seed producer farmers in some part of Amhara region, Ethiopia, was found to be 79.9 percent (Wassie, 2012). Another study (Kaleab and Birhanu, 2011) done on analysis of TE on wheat producing commercial farms in Ethiopia, confirmed as the average TE of farmers was limited to 82 percent, implying that there is a room to enhance productivity by 18 percent. However, even though there are many studies done by different scholars in the country, they are all either area and/or crop specific. To the best of my knowledge, that analyzed both TE and determinants of inefficiency in the production of major crops in Ethiopia, simultaneously. Hence, this study tries to address the following objectives using the Ethiopian Rural Household Survey (ERHS) data collected from biggest 4 regions of the country.

1.2 Objectives and Research Questions

The major objective of this study is to evaluate the efficiency and identify factors that explain the variation in inefficiency of crop production in Ethiopia. Alternatively, this research was done to answer the following research questions.

Objectives:

Specifically, this study has the following objectives:

1. To examine the level technical inefficiency of small-scale major crop production in the country.

2. To explore socioeconomic and biological factors explaining the variation in technical inefficiency among small-scale major crop production in the country.

Research Questions:

1. Is there a potential to reduce the production inefficiency of major crops, given the current production technology? If yes, by what percent?
2. Are there socioeconomic and biological factors that explain the variation in production inefficiency of major crops? If yes, what are they?

The remaining parts of the thesis unfold as follows. Chapter two deal with in-depth review of both theoretical and empirical literatures on TE. Chapter three briefly explains the methodology, which basically includes data type and source, model specification and method of analysis. Chapter four is result and discussion part of the thesis. The last, but not least, chapter will be devoted to the conclusion of the study.

2 Literature Review

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

2.1 Theoretical Literature Review

Productivity and efficiency are both measures of production performance. However, there is slight difference between them. One can improve the state of technology by inventing new ploughs, pesticides, etc. This is commonly referred to as technological change and can be represented by an upward shift in the production frontier. Alternatively, one can improve farmers` education, extension service, etc. This in turn will improve production efficiency of farmers and will be represented by farmers operating more close to the existing frontier. Hence generally, productivity growth may be achieved through either technological progress or efficiency improvement (Coelli, 1995)

2.1.1 Concept of Efficiency

The simple and straight forward way of measuring efficiency of a farm could be yield per hectare. However, given output is a function of multiple inputs in the reality, this is very simplistic way of measurement in that it only considers a single input of production, land. The other technique is to use the conventional econometric analysis, which generally assumes that all producers always manage to optimize their production process. However, there are discrepancies between production amount and production values even if the enterprises have identical technological constraints. This depends upon different productive capabilities and less favorable utilization resources by some enterprises (Burhan, Ceylan, and Hatice, 2009). The traditional, least squares-based, regression techniques attribute all departures from the optimum exclusively to random statistical noise. However, producers do not always succeed in optimizing their production. Therefore, it is desirable to recast the analysis of production away from the traditional functions towards frontiers (Kumbhakar and Lovell, 2000). Thus production frontier characterizes the minimum input bundles required to produce a given level of output or the maximum possible level of production of output from a given level of inputs, commonly called technical efficiency. Even though there is some similarity between terms production efficiency and technical efficiency, however, they are not same. The simplest way to differentiate production and technical efficiency is to think of productive efficiency in terms of cost minimization by adjusting the mix of inputs, whereas TE is output maximization from a given mix of inputs (Palmer and Torgerson, 1999).

According to Coelli (1995) in analyzing efficiency, fitting a frontier model performs better than Ordinary Least Square (OLS) regression. The two main benefits of estimating the frontier function, rather than average (e.g. OLS) functions, are that:

i. Estimation of an average function will provide a picture on the shape of technology of an average firm, while the estimation of the frontier function will be most heavily influenced by the best performing firm and hence reflect the technology they are using.
ii. The frontier function represents a best practice technology against which the efficiency of firms within the industry can be measured. It is this second use of frontiers, which leads to widely application of estimating frontier functions.

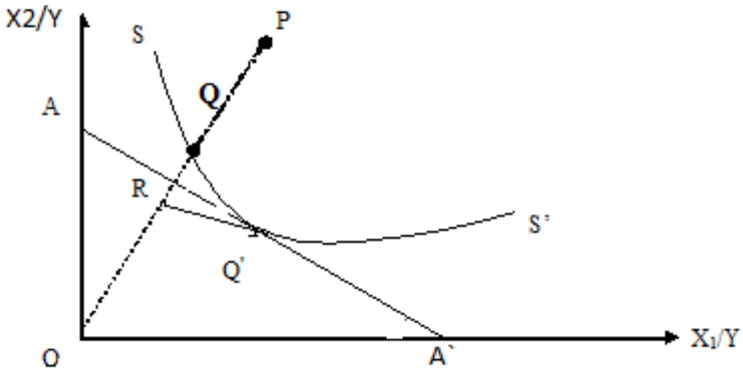
2.1.2 Approaches of Measuring Efficiency

Basically there are two approaches in measuring efficiency: input oriented and output oriented. The output oriented approach deals with the question “by how much output could be expanded from a given level of inputs?” Alternatively one could ask “by how much can input of quantities be proportionally reduced without changing the output quantity produced?” This is an input oriented measure of efficiency. However, both measures will coincide when the technology exhibits constant returns to scale, but are likely to vary otherwise (Coelli and Battese, 2005).

Input oriented measure

In his first work on efficiency, Farrell (1957) illustrated his idea about measuring efficiency with figure, as follow. The SS' is an isoquant, representing technically efficient combinations of inputs, X_1 and X_2, used in producing output Q. SS' is also known as the best practice production frontier. AA' is an isocost line, which shows all combinations of inputs X_1 and X_2 to be used in such a way that the total cost of inputs is equal at all points. However, any firm intending to maximize profits has to produce at Q', which is a point of tangency and representing the least cost combination of X_1 and X_2 in production of Q. At point Q' the producer is economically efficient.

Figure 1 Input oriented measures of technical efficiency



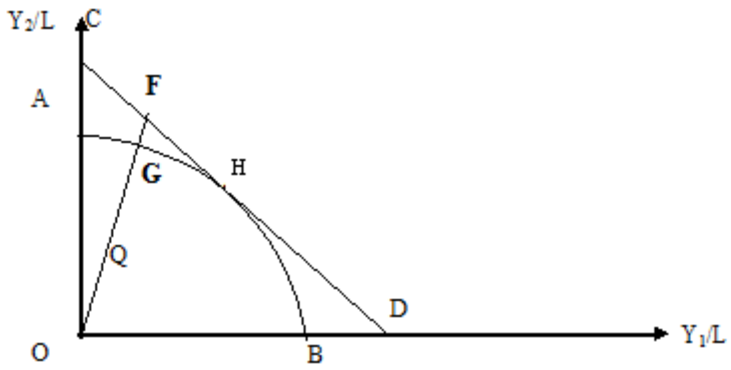
Source: Coelli (1995).

Given figure 1, suppose a farmer is producing his output depicted by isoquant SS' with input combination level of (X_1 and X_2). Production at input combination at point P is not technically efficient because the level of inputs needed to produce the same quantity is Q on isoquant SS'. In other words, the farmer can produce at any point on SS' with fewer inputs (X_1 and X_2), in this case at Q in an input-input space. The degree of TE of such a farm is measured as OQ/OP, which is proportional in all inputs that could theoretically be achieved without reducing the output. Hence all farmers that produce along the isoquant are 100 percent technically efficient (*ibid*).

Output oriented measure

In the output oriented perspective, efficiency is evaluated keeping inputs constant. According to Farrell (1957), output oriented measures can be illustrated by considering the case where production involves two outputs (Y_1 and Y_2) and a single input (L). If the input quantity is held fixed at a particular level, the technology can be represented by a production possibility curve in two dimensions as follows:

Figure 2 Output oriented measures for technical efficiency



Source: Coelli, Rao, and Battese (1998).

The production possibility curve is represented by the curve AB in Figure 2, which represents technically efficient combinations of production of outputs Y_1/L and Y_2/L. Given same level of input (L), it is not efficient to produce at point Q. Considering a firm situated at point Q, the TE can be calculated as OQ/OG. Alternatively, all farmers producing along the production possibility curve are 100 percent technically efficient.

2.1.3 Efficiency Models

Starting from the first empirical application of Farrell (1957) several different approaches of frontier estimation and efficiency score calculation have been developed. Efficiency measurements basically are carried out using frontier methodologies, which shift the average response functions to the maximum output or to the efficient firm. Essentially there are two main methodologies for measuring TE: the econometric (parametric) approach, and the mathematical (non-parametric) approach. The parametric models are estimated based on econometric methods (Coelli, Rao and Battese, 1998) and the non-parametric methods of measuring productive inefficiency are broadly speaking dependent upon classification of quantitative and qualitative variables under the well-known methodology of Data Envelopment Analysis (Burhan *et al.*, 2009). Efficiency measures assume as production function of the fully efficient firm is known. But this is not possible in the reality; hence the efficient isoquant must be estimated from the sample data taking the relatively best performing firms as fully efficient (Coelli *et al.*, 1998). Given parametric approach is used in this study; I have reviewed the current literatures on parametric frontier models very briefly as follows.

Parametric frontier model can further be classified into deterministic and Stochastic Frontier Production (SFP) model. The very basic difference between the two models is on their assumption about the error term. The deterministic model assumes that any deviation from the frontier is due to inefficiency, while the stochastic approach allows for statistical noise.

Non- stochastic/deterministic

According to Coelli (1995), this model doesn`t take account the possible influences of measurement errors and other noises up on the shape and positioning of the estimated frontier. Alternatively, any deviation from the frontier will be taken as inefficiency. Non-stochastic/deterministic production frontier can be estimated using linear programming or econometric techniques such as Corrected Ordinary Least Square (COLS). Application of this model, especially in cases where there is high probability of measurement risk, will exaggerate the inefficiency estimates as compared to the models which decompose the error term in to two components.

Aigner and Chu (1968) specified a non-stochastic or deterministic frontier model of Cobb Douglas production function for a sample of N firms as:

$$\ln(Y_i) = F(X_i;\beta_i) - U_i \quad , i = 1,2,\ldots N \qquad 2.1$$

Where Y_i is the output of the i^{th} firm; X_i is the vector of input quantities used by the i^{th} firm; β is a vector of unknown parameters to be estimated; F (.) denotes an appropriate function (Cobb Douglas); and U_i is a non-negative variable representing the inefficiency in production.

Stochastic frontier production function

To solve the limitation of deterministic approach of Aigner and Chu (1968), Timmer (1971) designed a method that involves dropping a percentage of firms closest to the estimated frontier, and re-estimating the frontier using the reduced sample. The arbitrary nature of the selection of some percentage of observation to omit has meant, however, that Timmer's probabilistic approach has not been widely followed (Coelli, 1995). In the process of managing the outliers, so that the inefficiency level would not be exaggerated, firms/farmers who outperform will be considered as outliers.

According to Kumbhakar and Lovell (2000), SFP function originated with two papers, published nearly simultaneously by two teams on two continents. Meeusen and Van den Broeck (1977) appeared in June, and Aigner, Lovell and Schmidt (1977) appeared a month later. Unlike the deterministic model, SFP function has a disturbance term with two components; the error component (v) and the stochastic noise (u). The other merit of the SFP function over the former (deterministic) is that the estimation of standard errors and tests of hypothesis is possible, which the deterministic model fails to fulfil because of the violation of the maximum likelihood regularity conditions (Coelli, 1995). Stochastic frontier production function can be estimated using Maximum likelihood (ML) or COLS method. Unless one uses COLS for its simplicity, the ML method is asymptotically efficient and hence recommended to be used than COLS (Coelli, 1998).

2.2 Empirical Literature Review

In this subchapter of the literature, recent studies done on efficiency are reviewed. As the current study deals with TE, more weight is given to empirical researches on TE done in different parts of the world. Most of the studies done in the area of TE, focus on the TE of single crop production. Generally, literatures from Ethiopia and elsewhere in the world that are done on efficiency are reviewed as follows.

A study done in Borno State of Nigeria using data collected from 1086 sample farmers in 2004, reveal that farm size, fertilizer and hired labor were the major factors that determine output of food crops (Amaza, Bila and Iheanacho 2006). According to their study, the effect of land area, Fertilizer and hired labor were found to have positive effect on output, as expected. Mean farmers' TE index was found to be 68 percent. Farmer-specific factors that account for the observed variation in efficiency among the farmers' efficiency factors were age, education, credit, extension and crop diversification. Their study output implied that, TE in food crop production of the study area could be increased by 32 percent through better use of available resources, given the current state of technology.

Fasasi (2007) used a stochastic frontier production (Maximum Likelihood Estimation, MLE) methodology to estimate the TE of food production in Oyo State, Nigeria. The estimated mean level of TE was 70 percent, ranging between 18 percent and 93 percent, indicating that with the present technology there is still room for a 30 percent increase in food production. According to his result, age of farmers affects TE positively and significantly whereas farming experience and level of education have negative and significant influence on the level of TE.

Kehinde and Awoyemi (2009) used a stochastic frontier approach to estimate a Cobb Douglas production function in analyzing the TE of sawn production in Ondo and Osun states, Nigeria. According to their study, using sample of 170 sawn wood producers, there was high potential (by 32 percent) to increase TE. The study prevailed as saw millers' level of efficiency could be improved if sawlog, electricity and capital are effectively used.

A region wise analysis of efficiency was done in different regions of India as well as in the state of Punjab to show how different regions have adopted the latest technology (Sekhon, Amrit, Manjeet and Sidhu, 2010). They estimate farm level TE using stochastic frontier production function analysis. According to their study, the main drivers of efficiency were experience in agriculture and age of a farmer. The TE has shown a wide variation across regions. The average TE has been found maximum in the central region (90 percent), followed by south-western and sub-mountainous regions. Hence they recommended as the state would benefit more from policy intervention if policy interventions are developed at the local level.

Huynh and Mitsuyasu (2011) made an effort to measure the TE of rice production and identified some determinants of TE of rice farmers in Vietnam. They used Vietnam household living standard survey 2005-2006 and analyzed using stochastic frontier analysis method. In their study using the Cobb-Douglas production functional form, the mean level of TE was found to be 81.6 percent. According to their study, the most important factors having positive impacts on TE levels were intensive labor in rice cultivation, irrigation and education.

Shumet (2011) used survey data collected by Tigray Microfinance in the year 2009 to estimate small holder farmers' TE and its principal determinants. He used both descriptive and econometric methods of analysis. In his study, he has tested the functional form, existence of inefficiency, and the joint statistical significance of inefficiency effects. The maximum likelihood parameter estimates showed that except labor all input variables have positive and significant effect on production. According to the study, the mean TE of farmers was 60.38 percent implying that output in the study area can be enhanced by 39.62 percent using same level of input and the current technology. The estimated stochastic frontier production function revealed that education of household heads, family literacy, family size, share cropping, credit access, crop diversification, and land fertility were found to have a positive and significant effect on efficiency. In contrast, Households' age, dependency ratio, livestock size, and off-farm activity affect efficiency negatively and significantly.

A study done by Abba (2012) on the technical efficiency of sorghum production and its determinants used stochastic frontier production function which incorporates a model of inefficiency effects. He used farm level data collected from a sample of 100 sorghum farmers in Hong local government area of Adamawa state. According to his study, land, seed, and fertilizer were the major factors that influence changes in sorghum output and education, extension contact and household size were major explanatory variables that had significant effects on the technical inefficiency among the sorghum producers. The TE of farmers varied from 15.62 to 92.14 percent with a mean TE of 72.62 percent. The implication of the study is that efficiency in sorghum production among the farmers could be increased by about 27 percent through better use of land, seed and fertilizer in the short term given the prevailing state of technology. In his study, Abba (2012), recommended policy interventions by the government in terms of better access to land, improved seed and fertilizer.

In an analysis of technical efficiency in Northern Ghana using bootstrap DEA, the average TE of crop production was found out to be 77.26 percent. This indicates as nearly 23 percent production loss is due to technical inefficiency (Luke, Atakelty and Amin, 2012). The estimated scale efficiency was 94.21 percent. They used a two stage estimation method, which they found hired labor, geographical location of farms, gender and age of head of household significantly affect TE.

The empirical evidence obtained from small scale wheat seed producer farmers in Ethiopia prevails that, on average, the total wheat seed production can be enhanced by nearly 20 percent, keeping inputs and current production technology constant (Wassie, 2012). Alternatively, the mean TE of sampled households was 79.9 percent. Wassie (2012) used Cobb Douglas production function, to determine elasticity of inputs and the level of efficiency of each producer. He applied a two-stage estimation method. He used the estimated level of efficiency as dependent variable in the Tobit model which was used to determine factors that affect efficiency. Accordingly, interest in wheat seed business (dummy) and total income positively and significantly affect TE while total expenditure has a negative and significant effect.

Dawit, Jerey, and Esendugue (2013) estimate a distance function of grain production using generalized method of moments that enabled them to accommodate multiple outputs of farmers as well as address the endogeneity issues that are related with the use of distance functions for multi-output production. They used a panel data set of Ethiopian subsistence farmers, and found that the most important factors determining farmers' efficiency in Ethiopia are having access to the public extension system, participation in off-farm activities, participation in labor sharing arrangements, gender of the household head, and the extent to which farmers are forced to produce on marginal and steeply sloped plots. According to their study, farmers in Ethiopia are producing less than 60 percent of the most efficient farmers, on average. Moreover, the annual technical change between 1999 and 2004 is about one percent while annual efficiency change during the same period is insignificant.

A study undertaken in southern Ethiopia with the objective of assessing productivity and technical efficiency of smallholder farmers, based on the data collected from 385 randomly selected farmers, indicated as there was significant level of inefficiency among maize producing farmers (Geta *et al.,* 2013). They used a two stage estimation technique, translog production function to determine the levels of TE followed by Tobit regression model to identify factors influencing TE. The model result depicted that productivity of maize was significantly influenced by the use of labor, fertilizer, and oxen power. The mean TE was found to be 40 percent and important factors that significantly affected the TE were agro-ecology, oxen holding, farm size and use of high yielding maize varieties.

The literature review above prevails that Cobb Douglas production function has wider application in analysis of efficiency. More importantly, only limited researches applied one stage approach of analyzing efficiency, even though this has advantage over the commonly used two stage approach. Hence this study will contributed additional literature, by analyzing efficiency of each crop type and the aggregate major crops and determinants of inefficiency simultaneously using one stage estimation method.

3 Methodology

3.1 Study Area Description

Ethiopia, a country located in the Horn of Africa, has a land area of about 1.1 million square kilometer and a population size of 93,877,025 million people in 2013. Ethiopia is bordered on the west by the Sudan, the east by Somalia and Djibouti, the south by Kenya, and the Northeast by Eritrea (CIA 2013).

Figure 3 Map of Ethiopia

Source: *ibid*

According to the same source (CIA 2013) the per capita GDP, using purchasing power parity, of the county is limited to 1200 dollar. Ethiopian economy is based on agriculture, which accounts for 41 percent of GDP, 80 percent of exports, and 80 percent of the labor force. The country mainly exports primary goods; coffee, khat, gold, leather products, live animals and oilseeds. The country produces more coffee than any other nation on the continent. Coffee is one of Ethiopia's main exports. Ethiopia is also the 10th largest producer of livestock in the world. Recent development of the floriculture sector means Ethiopia is poised to become one of the top flower and plant exporters in the world. However, generally agricultural production is overwhelmingly of a subsistence nature, and a large part of commodity exports are provided by the small scale producers in the country.

3.2 Types and Sources of Data

This study principally used the 2009 Ethiopia Rural Household Survey (ERHS) which is collected by International Food Policy Research Institute (IFPRI). The latest data available which is collected in the year 2009 was used for this study. In the survey a total of 24 villages composed of four biggest regions, Oromiya, Amhara, Tigray and Southern Nationions` and Nationality People (SNNP), were covered giving a total sample of 1477 households. The villages were selected in such a way that the data will account for the diversity in the farming systems in the country. Topics addressed in the survey include household characteristics, agriculture and livestock information, food consumption, health, women's activities, as well as community level data on electricity and water, sewage and toilet facilities, health services, education, NGO activity, migration, wages, and production and marketing. Given that it is national data collected in different parts of the country with different agroecology and measurment unit, there may be some level of problem with the quality of the data. However, as this is 5th round survey, their experience in data collection would reduce the error relative to past round surveys.

The ERHS 2009 data was originally organized differently, than used in this study, so STATA data management methods (recode, merge, filter, etc.) were used to reorganize the data set. From the total bulky data set, containing 108 files, those data sets with important variables for the study were chosen and managed in such a way that it will be ready for analysis, plot level. As a result, the total number of observation used in this study comes to be 3183 (Table 1).

In addition to the ERHS 2009 data, research articles on Ethiopian economy, crop production and productivity were also consulted. Moreover, a number of research articles, books and journals done on area of efficiency were critically reviewed in the study.

Table 1 Distribution of sample by region and crop type

Region	Crop type produced in the year 2009							
	White teff	Black teff	Barley	Wheat	Maize	Sorghum	Horse Bea	Total
Tigray	0	0	18	6	0	0	2	26
Amhara	177	121	236	52	9	135	92	831
Oromiya	405	81	113	367	574	239	37	1819
SNNP	61	14	5	30	389	0	8	507
Total	643	216	372	455	972	374	139	3183

Source: Own computation (2013)

Based on population size, Oromiya is the largest regional state followed by Amhara, SNNP and Tigay, accordingly. The sample size also follows the same order across regions. Out of the total sample size of 3183, samples from Oromiya region takes nearly 57%out of which again majority (574) of them are maize plots. Regardless of the regional category, the highest observation belongs to maize plot covering 972 out of the total 3183. Following maize, white *teff* and wheat were also represented by significant number of observation, 643 and 455 respectively.

3.3 Method of Analysis

The analysis basically employed both descriptive and Econometric methods. Descriptive statistics (mean, percentage, range, etc.) is used to summarize the variables used in the model and describe the study area. Econometric model, SPF model, is employed to estimate the elasticity of production function, determine the determinants of inefficiency and estimate the level of efficiency. Before embarking on the model specification and analysis methods, it's crucial to start by defining the variables.

3.3.1 Variable Definition

The variables that are used both in the production functions[2] and determinants of inefficiency are here defined briefly as follows. All inputs and outputs were transformed to their corresponding log values in estimating the Cobb Douglas production function. As the log value of zero is undefined, for the variables out of which production is possible (urea and DAP[3]) zero values in the data set were changed to nearly zero (0.0001) value before transforming the data to log form.

Output (OUTPUT): Output, which is the dependent viable in the estimation of production functions, is measured in kilograms (Kg). The data was collected using different local measurement units of output, however for uniformity it was changed to the standard measurement unit, kilogram. Hence output measured in Kg was used in the analysis.

Inputs: This refers to explanatory variables used in the estimation of production functions.

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[2] In this study, total of four production functions were fitted, independently. The variable definitions are same for all functions. Specific to major crops production function, it refers to all observations of plots producing White teff, Black teff, Barley, Wheat, Maize, Sorghum and Horse Bea (table 1).

[3] DAP refers to Di Ammonium Phosphate.

1. Land (LAND): This refers to the area of plot of land allotted for crop production. The unit of measurement for area is also different in different parts of the country; hence the data was changed to hectare for smoothness. Accordingly, hectare of plot of land used for crop production was used in the analysis.

2. Urea (UREA): Urea and DAP, most commonly used fertilizers in Ethiopia, are an important inputs for production. Unlike the old days, there is an increased demand and use of these fertilizers in Ethiopia (Kefyalew, 2011). Hence, total Urea/DAP applied on plot of land per Kg was used in this study.

3. Seed (SEED): This refers to the amount of seed used in the production of output. Hence, total amount of seed used in Kg was used for the analysis.

4. Human Labor (LABOR): This input captures family, shared and hired labor used for different agronomic practices of crop production. But the differences in sex and age among labor would be expected. Hence to make a homogeneous group of labor to be added, the individual labor was changed in to Man Days (MDs) using the standard (Storck, 1991 as cited in Arega and Rashid, 2005). Therefore, the human labor input is expressed in terms of total MDs employed to perform land preparation, planting, input application, cultivation, harvesting and threshing.

Determinants of Inefficiency: These socioeconomic and biological variables, chosen in reference to former studies and logical reasoning, are used in identifying the determinants of inefficiency. Most literatures used to analyze determinants of efficiency rather than inefficiency. However, the only difference between them is only on the interpretation.

- Age (AGE): This refers to the age of the household head measured in years.
- Education (EDUCATION): This is educational level of the household head measured in years of schooling, giving zero value for illiterate.
- Knowledge about land policy (LANDPOLICY): This is a dummy variable measured as 1 if farmers know about the land registration/certification[4] process and 0 otherwise.

[4] Refer Abebe (---) for details about land registration process in Ethiopia.

- Soil and Water Conservation (SWC): This is a dummy variable measured as 1 if farmers adopted soil and water conservation practice and 0 otherwise

- Extension contact (EXTFREQ): As part of agricultural extension system, there are three agricultural extension experts that deal with helping farmers in adopting new technologies and enhancing productivity in every kebelle[5], in Ethiopia. This variable is measured as the frequency of contact of a farmer with the extension workers in 2009 production year.

- Poverty status (POVSTAT): This refers to the perception of farmers about their status of poverty compared to their community. This is a dummy variable measured as 1 if they perceive as they are above average level of poverty, compared to the community or 0 otherwise.

- Off-farm income (OFFINCOM): This is also a dummy variable which is measured as 1 if one of the household members participate in off-farm activity in the last four months (which is production season counting back starting from survey period) or 0 otherwise.

- Plot fertility (FERTILITY): Farmers were asked to rate the relative fertility status of their plots, hence this variable is a dummy with 1 for fertile and 0 otherwise.

- Slop of plot (SLOP): In the ERHS 2009 data, farmers were asked to rate slop of their plot as flat, moderate and steep. For this study, the data was recoded as 1 if the plot is flat and 0 otherwise.

- Livestock (TLU): This is the total number of livestock of the household in terms of Tropical Livestock Unit (TLU).

- Adopt improved seed (IMPSEED): The dummy variable for adoption of improved seed assigns the value of 1 if the respondent has used improved seed and 0 if not.

3.3.2 Model Specification

[5] Kebelle is the smallest administration unit in Ethiopia.

Given that we are considering a developing country setting where by the main concern is output shortfall rather than input over use, preference has been given to primal or output oriented approach of measuring efficiency. Moreover, in this study one stage approach[6] in which both technical efficiency and factors of inefficiency are analyzed simultaneously was used.

Cobb Douglas production function has been employed in many researches done on analyzing efficiency of agricultural production, as it is shown in the empirical literature review part of this thesis. Hence, it was adopted for the current study on hand.

Following Aigner *et al.* (1977) and Meeusen and van den Broeck (1977), the SFP function model can be defined as:

$$\ln Y_i = \beta_o + \sum_{j=1}^{n} \beta_j \ln X_{ij} + \sum_{k=1}^{m} \alpha_k \ln z_{ik} + \varepsilon_i$$
$$\varepsilon_i = v_i - u_i \qquad (3.1)$$

Independently, the model was fitted for each crop type. Here ln denotes the natural logarithm; *n* represents the number of inputs used; *m* represents the number of explanatory variables used in the model; *i* represents the i[th] plot in the sample; Y_i represents the observed production for each of the major crops produced on i^{th} plot; X_{ij} denotes j^{th} farm input variables used for major crop produced on i^{th} plot and similarly Z_{ik} denotes k^{th} inefficiency explanatory variables; *ß* and α stands for the vector of unknown parameters to be estimated; ε_i is a composed disturbance term made up of two elements (v_i and u_i). The random error (v_i) accounts for the stochastic effects beyond the producer's control, measurement errors as well as other statistical noises and u_i captures the production inefficiency.

Aigner *et al.* (1977) proposed the log likelihood function for the model in equation (3.1) assuming half normal distribution for the technical inefficiency effects (u_i). They expressed the likelihood function using λ parameterization, where λ is the ratio of the standard errors

[6] Refer Gebreegziabher, Oskam and Woldehanna (2004) for comparative advantage of primary approach over the two stage approach.

of the non-symmetric to symmetric error term (i.e. $\lambda = \sigma_u / \sigma_v$). As it could be envisages, the parameter λ is an indicator of the relative variability of the two sources of variations. A value of λ greater than 1 implies that the discrepancy between the observed and the maximum attainable levels output is dominated by variability emanating from technical inefficiency (Gebreegziabher *et al.,* 2004).

Alternatively, Battese and Corra (1977) proposed the Log Likelihood (LL) function for the model in equation (3.1) assuming half normal distribution for the technical inefficiency effects (u_i). They expressed the likelihood function using γ parameterization, where $\gamma = \sigma^2{}_u / (\sigma_v{}^2 + \sigma_u{}^2)$, instead of λ. The reason is that λ could be any non-negative value while γ ranges from zero to one and better measures technical inefficiency. Following Bravo and Pinheiro (1997), gamma (γ) from lambda (λ) have the following relationship:

$$\gamma = [\lambda^2 / (1 + \lambda^2)] \qquad (3.2)$$

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

$$\ln(L) = -\frac{N}{2}\left(\ln\left(\frac{\pi}{2}\right) + \ln\sigma^2\right) + \sum_{i=1}^{N} \ln\left[1 - \Phi\left(\frac{\varepsilon_i\sqrt{\gamma}}{\sigma^2}\sqrt{\frac{\gamma}{1-\gamma}}\right)\right] - \frac{1}{2\sigma^2}\sum_{i=1}^{N} \varepsilon_i{}^2 \qquad (3.3)$$

Where $\varepsilon_i = \ln Y_i - \ln X_i \beta - \alpha_k \ln z_{ik}$ is the residual of (3.1); N is the number of observations; $\Phi(.)$ is the standard normal distribution; $\sigma^2 = \sigma_v{}^2 + \sigma_u{}^2$, and $\gamma = \sigma_u{}^2 / \sigma^2$ are variance parameters. The minimization of (3.3) with respect to β, σ^2, α and solving the resulting partial derivatives simultaneously, produces the ML estimates of β, σ^2, and α.

The existence of inefficiency can be tested using γ parameter and can be interpreted as the percentage of the variation in output that is due to technical inefficiency. Likewise the significance of δ^2 indicate whether the conventional average production function adequately represent the data or not.

4 Result And Discussion

Chapter four consists of both descriptive and econometric results of the study. Specific to econometric part, results were discussed by comparing and contrasting with other research findings.

4.1 Descriptive Statistics

In this sub-chapter, I will use descriptive statistics to figure out the study area regarding input use and crop production.

According to Abu and Quintin (2013) grain production constitutes the major share of agricultural production and contributes significantly to the national domestic product, in Ethiopia. Around 98 percent of cereals are produced by small landholder farmers. They argued as fragmented nature of land holdings and low use of agricultural inputs contributes to low levels of grain productivity in the country.

Table 2 Area coverage, production and productivity of major crops in 2012/13.

Crop type	Area (1000 ha)	Production (1000 MT)	Productivity (MT/ha[7])

[7] ha refers to Hectare and MT for metric tonne

Maize	2150	5500	2.558
Teff	3760	3769	1.002
Sorghum	1780	3570	2.006
Wheat	1510	3200	2.119
Barley	1015	1620	1.596
Millet	440	680	1.545
Total	10,655	18,339	1.721

Source: Abu and Quintin (2013).

Production of maize takes the lead in terms of quantity of output produced in Ethiopia. It accounts for 22 percent of the total area covered by cereal and around 30 percent of the total cereal production. In addition to the highest total production per annum, maize is also the single most important crop in terms of high productivity. The productivity of cereals vary from 1.002 MT/ha of *teff* to 2.558 MT/ha for Maize, averaging 1.721 in the 2012/13 production year. *Teff* is a staple food in Ethiopia, which appears in everyone's dishes of everyday life. *Teff* is originally from Ethiopia, however, these days given it is gluten free cereal it is being consumed in many other countries as well. Despite of its lowest productivity, among cereals, it takes the lead in terms of area of production. Sorghum is the fourth largest cereal crop in Ethiopia and is produced in most parts of the country. It is noted for its diversity and is produced over a wide range of agro-ecological zones, having average productivity of 2.006 MT/ha. Barley is the fifth most important cereal crop after *teff,* wheat, corn, and sorghum. It is the staple food grain especially for Ethiopian highlanders who produce the crop with indigenous technologies (table 2).

Ethiopia is the second largest wheat producing country in Africa next to South Africa. Wheat is mainly grown in the central and south eastern highlands; Arsi, Bale, and parts of Shoa are considered the wheat growing belt. Bread wheat is the major variety of wheat grown in Ethiopia. However, farmers grow durum and bread wheat (mixed together) in some parts of the country. Total import by 2011/12 is 1,050,000 metric tons. Productivity in same year is 2.11 MT/ha (*ibid*).

Table 3 Summary of variables used in the estimation of production functions

Variables	Major crops	White-*teff*	Wheat	Maize
OUTPUT	570.99	484.71	860.12	604.15
	(717.18)	(1050)	(822.1)	(615.78)
LAND	0.675	0.538	0.462	1.17
	(5.83)	(0.486)	(0.348)	(10.54)
DAP	19.88	21.23	36.177	12.74
	(34.17)	(28.48)	(42.53)	(21.35)
UREA	8.48	10.75	3.26	13.73
	(23.99)	(20.31)	(8.45)	(33.97)
SEED	37.21	30.42	83.44	22.19
	(87.10)	(49.07)	(94.75)	(95.25)
LABOR	99.32	116.62	89.48	104.31
	(150.44)	(176.62)	(106.29)	(168.51)

Note: the values in the bracket are standard errors.

Source: Own computation (2013).

The dependent variable in estimation of the production function is output, measured in Kg, for all four models fitted independently. According to table (3), the average production of output from the sample of major crop production plots was 570.99 Kg, with standard error of 717.18. The average output for White-*teff*, wheat and maize was also 484.71, 860.12 and 640.15 Kg respectively. As far as the input variables in the production function is concerned, total of five variables were considered. The average area of plots, measured in hectares, was found to be less than one for all except maize. The other input used in estimation of the production functions is DAP. The average amount of DAP used per plot was highest on wheat plots (36.177 Kg) followed by *teff* plots (21.23Kg). Generally, farmers usage of DAP per plot of land for major crops was calculated to be nearly 20Kg. Farmers also use urea in the production of crops, mainly cereals. The average use of urea per plot was the highest (10.75 Kg) in *teff* production. The other input, in which production is impossible out of it, is seed. Farmers use much seed per plot, 83.44 Kg with standard error of 94.75, compared to other crops. Last, but not least, labor was also considered as an input variable in the estimation of frontier models. The average labor used per sample plots, measured in man-days, ranges from 89.48 for wheat to 116.62 for *teff*.

Table 4 Summary of continuous variables used in the inefficiency models

Variables	Observation	Mean	Std. Dev	Min	Max
AGE	2955	49.89	14.04	18	100
EDUCATION	2953	2.868	3.44	0	14
EXTFREQ	2996	1.806	4.51	0	24
TLU	3188	6.20	5.23	0	59.03

Source: Own computation (2013).

This study used both continuous and dummy variables to explain the variation in output due to technical inefficiency. The summary of continuous variables used in the model (table 4) prevailed that the average age of sample plot owners was found to be nearly 50 years. Education, measured in years of schooling, of sample plot owners was limited to less than 3 years, on average. The other continuous variable used in the model is frequency of extension contact. The number of extension contact in 2009 production year was only 1.806, on average with the maximum contact of like 2 times per month. The average number of livestock, measured in terms of TLU, among sample was found to be 6.20.

Table 5 Summary of dummy variables used in the inefficiency model

Variables	Frequency		Percentage	
	Yes	No	Yes	No
LANDPOLICY	2879	124	95.71	4.12

SWC	1848	1140	61.44	37.90
POVSTAT	712	2288	23.73	76.27
OFFINCOM	1851	1157	61.54	38.46
FERTILITY	1875	1313	58.81	41.19
SLOP	2521	667	79.08	20.92
IMPSEED	751	2437	76.44	23.56

Source: Own computation (2013).

The variables depicted above (table 5) are dummy variables used in the inefficiency model. Among the total sample, 95% of them are aware of the land registration/certification policy in Ethiopia. The participants, on average, in soil and water conservation and off-farm activities were nearly equal (61 percent) for both. The other dummy variable tries to assess farmers` perception about their poverty status. Accordingly, only 23.44 percent of respondents were above the average level of poverty compared to their community. Among the sample plots, on average, nearly 79 percent were flat and 58.81 percent were rated as fertile. Last but not list, improved seed was adopted in more than 3/4 th of sample plots.

4.2 Econometric Results

In this sub chapter OLS and ML estimates of production functions, efficiency scores and determinants of inefficiency are presented and discussed clearly.

In this study an effort has been made to test the data against different possible econometric problems. Accordingly, the data was checked for hetroskedasticity using Breusch-Pagan test, and the result showed that there was no serious problem of hetroskedasticity. Multicollinearity test was done using Variance Inflation Factor (VIF) and specific to dummy variables contingency coefficient was also applied. Test for multicollinearity using both methodologies also confirmed as there is no serious linear relation among explanatory variables (Appendices 3 and 4).

4.2.1 Estimation of production function

This study tries to estimate production function using both OLS and MLE. STATA version 12 computer program was used to estimate the SFP function. Basically, before rushing to discuss the econometric model results, it is very important to test hypotheses of the study.

First, I tested whether the average production function best fit the data or not. Alternatively, this is to test whether the SFP function is more appropriate than the convectional production function or not. This can be done using the null hypothesis, H0: $\gamma = 0$, where the parameter $\gamma = [\lambda^2/(1+\lambda^2)]$. If this null hypothesis is not rejected, the SPF is equivalent to the convectional production function which is estimated by OLS. The γ parameter estimates of all production functions are significant at 5% significance level (table 7). Hence, the null hypothesis was rejected indicating SFP function is more appropriate than convectional production function or there is significant technical inefficiency variation among plots. The γ value of 0.636 for the major crops production function can be then interpreted as, 63% of the variation in output among plots is explained by technical inefficiency. Similarly, variation in out put due to technical inefficiency for *teff*, wheat and maize production were calculated to be 88.5, 45.5 and 77.8 percent respectively.

The second step, following the existence of inefficiency, is to check if there exist one or more variables that could explain the variation in technical inefficiency. Log likelihood ratio was used to test the hypothesis Ho: $\alpha_0 = \alpha_1 = \alpha_{3=} \ldots = \alpha_{11} = 0$. The LL ratio test can be computed as LL ratio = $-2[LLH_0 - LLH_1]$; where LLH_0 is the LL value of restricted Cobb-Douglas SFP model (a model without explanatory variables of inefficiency effect model) and LLH_1 is the LL value of the unrestricted model (a model with all explanatory variables of inefficiency effect model). Table (6) presents the generalized LL ratio tests for all models.

Table 6 Generalized likelihood ratio tests of hypothesis

	LL ratio value	Critical value

Crop type	Null hypothesis		(χ^2, 0.95)	Decision
Major crops	Ho: $\delta_1 = \delta_2 = . . . = \delta_{11} = 0$	271.9	19.68	Reject Ho
Teff	Ho: $\delta_1 = \delta_2 = . . . = \delta_{11} = 0$	91.66	19.68	Reject Ho
Wheat	Ho: $\delta_1 = \delta_2 = . . . = \delta_{11} = 0$	80.3	19.68	Reject Ho
Maize	Ho: $\delta_1 = \delta_2 = . . . = \delta_{11} = 0$	59.8	19.68	Reject Ho

Source: Own computation (2013).

The calculated value of LL ratio was compared to the critical values of LL ratio, with χ^2 distribution and 11 degrees of freedom to accept or reject the null hypothesis. Since all calculated LL ratio values are greater than the critical value of LL ratio, with upper 5 % level of significance, the null hypotheses that determinant variables in the inefficiency effect model are simultaneously equal to zero are rejected. In other words, there exists at least one explanatory variable that explains the variation in the technical inefficiency among plots.

Table 7 Estimates of the average and frontier production function

Variables	Major crops		*Teff*		Wheat		Maize	
	OLS	MLE	OLS	MLE	OLS	MLE	OLS	MLE
lnLAND	0.410[1]	0.3812[1]	0.898[1]	0.970[1]	0.666[1]	0.590[1]	0.685[1]	0.796[1]

lnUREA	0.017[1]	0.0189[1]	-0.035	-0.084	-	-	0.168[5]	0.027
lnDAP	0.031[1]	0.0320[1]	0.040	-0.071	0.040[1]	0.036[1]	0.011	-0.091
lnSEED	0.052[1]	0.0471[1]	0.122[1]	0.047	0.067[1]	0.049[1]	0.081	0.144[1]
lnLABOR	0.104[1]	0.0683[1]	0.050	-0.017	0.057[10]	0.030	0.086[5]	0.0192
Constant	5.956[1]	0.3812[1]	6.126[1]	7.792[1]	6.614[1]	6.932	6.052[1]	7.233
Adjusted R^2	0.3887	-	0.6611	-	0.6657	-	0.6830	-
F statistics	253.50[1]	-	61.49[1]	-	140.40[1]	-	0.6824[1]	-
$\sigma_u{}^2$	-	0.887[5]	-	0.841[5]	-	0.502[5]	-	0.695[5]
$\sigma^2 = \sigma_v{}^2 + \sigma_u{}^2$	-	1.236[5]	-	0.799[5]	-	0.553[5]	-	0.621[5]
$\lambda = \sigma_u / \sigma_v$	-	1.323[5]	-	2.773[5]	-	0.914[5]	-	1.872[5]
$\gamma = [\lambda^2/(1+\lambda^2)]$	-	0.636[5]	-	0.885[5]		0.455[5]	-	0.778[5]
LL	-	-2397.4	-	-88.27	-	-227.1	-	-99.53
Mean TE (%)	-	63.56	-	67.26	-	84.16	-	91.41

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

Source: Own computation (2013).

Total of five input variables were used in the estimation of the production functions, except for the estimation of wheat production function in which urea was dropped because of having many missing observations. Table (7) presents both OLS and ML estimates of production functions. The OLS estimate for major crop production shows as 38.87 percent of the variation in major crop output among plots was explained by the input variables. Similarly, 66.11, 66.57 and 68.30 percent of the variation in *teff*, wheat and maize output was explained by the explanatory variables. As far as the MLE results is concerned, all variables were found to be binding in the production of major crops, meaning that an increase in one of inputs will enhance production keeping everything constant. As far as *teff* production is concerned, only land was a significant variable that explains the variation in output among plots. Land, DAP and seed were found to have significant and positive effect in wheat production. According to result of this study, land and seed were major determinants of maize production in Ethiopia. Generally, all significant input variables were found to affect output positively, as expected (Table 7).

The MLE values of the coefficients can be interpreted as elasticity of production. For example a 1 percent increase in land will increase production of major crops by 0.38 percent, ceteris paribus. Moreover, the model output depicted that the mean level of TE for major crops, *Teff*, Wheat and Maize production was found to be 63.56, 67.26, 84.16 and 91.41 percent, respectively. The relatively lower value (63.56%) of TE score for major crops can be interpreted as, given the level of input and the current technology, there is a room to boost major crops production by 36.44 percent.

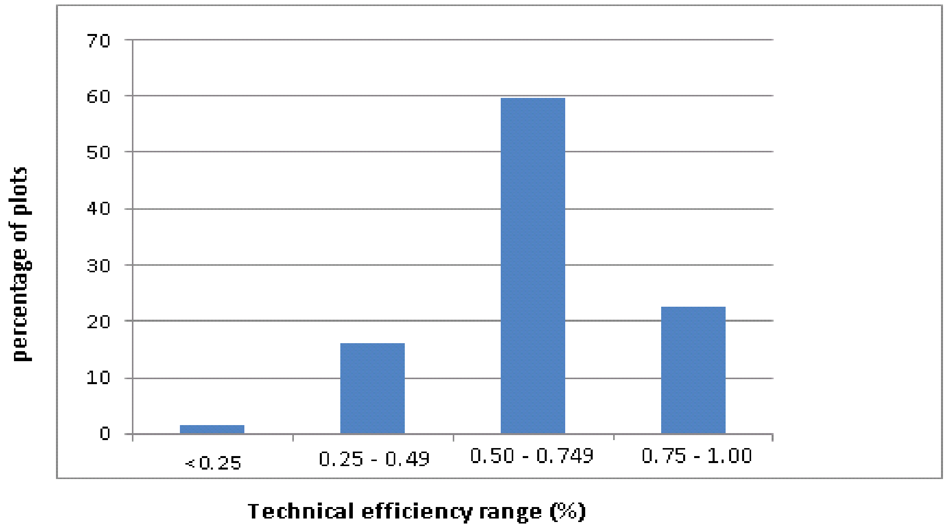
Table 8 Summary of efficiency scores by crop type

Variable	Observation	Mean	Std. dev	Min	Max
Major crops	1974	0.635	0.155	0.016	1.000
White *teff*	147	0.672	0.268	0.118	0.991
Wheat	275	0.841	0.170	0.965	1.000
Maize	267	0.857	0.179	0.266	1.000
Barely	107	0.616	0.142	0.025	0.887
Sorghum	333	0.285	0.201	0.001	1.000

Source: Own computation (2013).

The summary statistics of TE scores obtained from major crops production function shows that the relatively most efficient once are maize plots. However, even though they are relatively efficient there is still a room to enhance production by nearly 15%, ceteris paribus. The mean TE of sorghum plots was found to be relatively very inefficient, having 28% average level of TE (Table 8). Yield gaps are defined as the difference between yield potential and average farmers' yields over a given spatial or temporal scale. According to Kate and Leigh (2010) the yield gap for sorghum was calculated to be as high as 50%. For a country with significant grain supply shortage, it is not an option rather a must to enhance production by such huge amount without investing on capital and/or technology. However, as efficiency analysis is measured in reference to the best efficient farmer, if a more efficient farmer is included in the sample the figures may vary.

Figure 4 Distribution of technical efficiency estimates



Source: Own computation (2013).

As shown in figure (4), the distribution of the TE scores is skewed to the right. Majority (more than 80 %) of the sample plots have TE score greater than or equal to 50 %. More than 20% of sampled plots have a TE score above 0.75, meaning there is a room to enhance production by 25 percent. To the other end, there are also groups of sample plots with very low (less than 0.25) level of efficiency.

4.2.2 Estimation of determinants of inefficiency model

As explained in the model specification (3.1) one stage approach, which includes all inefficiency explanatory variables and conventional input variables simultaneously, was employed in this study. However, to make it readable the model results are presented with two tables, independently. Hence, the table below (table 9) presents the determinants of technical inefficiency among plots.

Table 9 Determinants of technical inefficiency.

Variables	Major crops		*Teff*		Wheat		Maize	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
AGE	0.007	0.0045	-0.040[5]	0.016	-0.030	0.027	0.187	0.142
EDUCATION	-0.092[1]	0.0265	-0.021	0.071	-0.372[1]	0.135	-0.141	0.216
LANDPOLICY	0.010	0.0436	2.293	1.698	-3.789[1]	1.127	1.373	3.529
SWC	-0.844[1]	0.1481	0.360	0.276	-2.250[5]	0.936	16.228	11.779
EXTFREQ	0.023	0.0223	-0.023	0.049	0.521[1]	0.141	1.814[5]	0.771
POVSTAT	-0.873[1]	0.2158	0.836	0.582	-0.580	0.861	-17.32	10.878
OFFINCOM	0.065	0.1247	1.070[1]	0.372	0.265	0.716	16.034	11.442
FERTILITY	-0.128	0.1307	-0.404	0.366	-1.419[5]	0.621	9.539	11.511
SLOP	0.035	0.1679	-1.851[1]	0.557	-0.910	0.828	-4.494[10]	2.605
TLU	-0.094[1]	0.0210	-0.225[1]	0.053	-0.175[10]	0.102	-1.622[5]	0.796
IMPSEED	-0.388[5]	0.1677	-0.615	0.480	0.547	0.901	-0.396	0.972
Constant	1.623[1]	0.6082	1.068	3.757	13.530[1]	3.712	-72.27	57.672

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

Source: Source: Own computation (2013).

Among many others, age of the household head measured in years was found to be the determinant of technical inefficiency, of *teff* production. There is a literature support for this result (Amaza *et al.,* 2006, Sekhon *et al.* 2010 and Shumet 2011). Age can serve as a proxy variable of farming experience, in which farmers with more years of experience are expected to be less inefficient. On the other hand, labor productivity decreases with age; younger farmers tend to be relatively more productive, because of the tough nature of farm operations (Ike and Inoni, 2006). Specific to this study, the first effect outweighs the second effect and age was found to affect inefficiency of *teff* production negatively and significantly. Alternatively, age has a positive and significant effect on TE of *teff* production.

Education can be a proxy variable for managerial ability of the farmer. Hence, it can be argued that farmers with better level of education are assumed to have less inefficiency. In line with this, education was found to have negative and significant effect on major crops and wheat technical inefficiency (1% significance level). The result is also in conformity to other studies (Amaza *et al.,* 2006, Fasasi, 2007 and Rahman, Mia and Bhuiyan, 2012).

Land is owned by the government in Ethiopia, and farmers have only use right. This has triggered less and less long term investment in maintaining fertility of the land. As a result, the government of Ethiopia has introduced land registration to create sense of belongingness on the land. As shown in table (9), knowledge about land policy was found to have significant and negative effect on technical inefficiency of wheat production (1% significance level). Similarly, participation in soil and water conservation activities was found to have negative and significant effect on technical inefficiency of major crops and wheat production.

In this study frequency of extension contact was found to have unexpected result. In principle extension service is a technical support concerning production technologies and ways to improve productivity; hence, it is expected to have negative effect on technical inefficiency. However, result of in this study shows the reverse correlation. The possible reasons for this could be: One, it could be because of problem of selection bias. Those farmers who need more technical support may be those who are inefficient in production, as the measure of extension in this study was frequency of contact. The second probable reason could be the quality of extension service. Practically, extension workers or development agents are actively involved in other political activities, besides their duty. Hence the more frequently the farmers meet extension works the more they compete their time for agricultural activities. As can be seen from table (4) there are farmers who contact up to 24 times per production year. Similar result was found in a study done on technical efficiency of barely production in Ethiopia (Hasson, Hassan, Mwangi and Kassa, 2000). They argued that the unexpected result of extension contact was due to biasedness in extension program in favor of wheat production in the study area. However, this result is in contrary to many other studies (Amaza *et al.* 2006; Abba 2012; Dawit *et al*., 2013).

Other economic variables that were found to affect technical inefficiency are poverty status and off-farm income. It can be argued that rich farmers, especially in developing countries where there is resource scarcity, are less inefficient than poor farmers. The result of this study also confirmed as rich farmers are relatively less inefficient than poor once, in major crops production. However, participation in off-farm activity could have both positive and negative effects on technical inefficiency. Being involved in off-farm activities, farmers may allocate more of their time to off-farm activities and thus may lag in doing their agricultural activities on due time. On the other hand, incomes from off-farm activities may be used as extra cash to buy agricultural inputs. Specific to this study, the first effect dominated the later one and off-farm income was found to have positive and significant effect on technical inefficiency of teff production. The result was consistent with Shumete (2011).

Plot specific inefficiency effect variables, fertility, slop and improved seed, are also other important determinants of technical inefficiency. As shown in table (9) fertility of a plot has significant and negative effect on technical inefficiency in wheat production. Alternatively, fertile plots of wheat are significantly less inefficient than infertile once. Similarly, flat teff and maize plots are more efficient than otherwise. There is also literature support (Shumete 2011and Dawit *et al*., 2013) for this finding. The other plot specific variable that was found to have negative and significant effect on technical inefficiency of major crop production was adoption of improved seed. Farmers who used improved seed at least on one of their plots are technically more efficient than otherwise.

The last, but not least, explanatory variable that explains variation in technical inefficiency is livestock ownership, measured in TLU. Livestock could support crop production in many ways; it can be source of cash, draft power and manure that will be used to maintain soil fertility (Wassie 2012). Accordingly, in this study the effect of livestock ownership on technical inefficiency was found to be negative.

5 Conclussion

Stochastic frontier production function was used to analyze efficiency of major crops production in Ethiopia. The hypothesis test on existence of inefficiency component in the error term shown that SFP function is more appropriate than convectional production function or there is significant technical inefficiency variation among plots. Accordingly, the γ value of 0.636 for the major crops production function can be then interpreted as, 63% of the variation in output among plots is explained by technical inefficiency. Similarly, variation in out put due to technical inefficiency for *teff*, wheat and maize production were calculated to be 88.5, 45.5 and 77.8 percent respectively. The LL ratio test was done to examine the null hypothesis, determinant variables in the inefficiency effect model are simultaneously equal to zero. Result of the test confirmed that the null hypothesis was rejected, meaning there exists at least one explanatory variable that explains the variation in the technical inefficiency among plots.

Result of the frontier production function indicates that all conventional input variables were found to be binding in the production of major crops, meaning that an increase in one of inputs will enhance production keeping everything constant. Generally, all significant input variables were found to affect output positively, as expected. Moreover, the model output depicted that the mean level of TE for major crops, *Teff*, Wheat and Maize production was found to be 63.56, 67.26, 84.16 and 91.41 percent, respectively. The TE value of 63.56 percent, for major crops, could be interpreted as there is potential to reduce the technical inefficiency by nearly 36 percent. The TE score of majority of the sample plots (>80 percent) is greater than or equal to 50 %. To the other extreme, there are also groups of sample plots with very low (less than 0.25) level of efficiency.

The inefficiency effect analysis for major crop production shown that education, participation in soil and water conservation activities, poverty status and adoption of improved seed are the major determinants. Off-farm income of the household head was found to affect technical inefficiency in teff production positively, contrary to this age of household head, slop and TLU were found to affect negatively.

The inefficiency in wheat production is mainly explained by participation in SWC activities, extension contact, education, fertility, TLU and knowledge about land policy. As far as the technical inefficiency of maize production is concerned, frequency of extension contact was found to have positive and significant effect.

An important conclusion stemming from this study is that, there exists a considerable room to reduce the level of technical inefficiency of teff, wheat, maize and major crop production in Ethiopia.

6 References

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7 Appendices

Appendix 1 Conversion factor used to calculate man equivalent.

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

Age group (years)	Man Days (MD)	
	Male	Female
<10	0	0
10-13	0.2	0.2
14-16	0.5	0.4
17-50	1.00	0.8
>50	0.7	0.5

Appendix 2 Conversion factors used to estimate Tropical Livestock Unit equivalents.

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

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

Appendix 3 Variance Inflation Factor (VIF) for input and inefficiency variables.

Variables	VIF	1/VIF
Input variables		
LAND	1.09	0.915745
UREA	1.18	0.846540
DAP	1.36	0.734147
SEED	1.22	0.822618
LABOR	1.13	0.886008
Inefficiency variables		
AGE	1.40	0.715048
EDUCATION	1.50	0.665998
LANDPOLICY	1.00	0.995265
SWC	1.05	0.951807
EXTFREQ	1.13	0.886264
POVSTAT	1.10	0.912151
OFFINCOM	1.07	0.934859
FERTILITY	1.12	0.891312
SLOP	1.10	0.912063
TLU	1.02	0.981434
IMPSEED	1.19	0.840628
Mean VIF	**1.17**	

Source: Own computation (2013)

Appendix 4 Contingency coefficient of dummy efficiency variables.

Variables	LANDPOLICY	SWC	POVSTAT	OFFINCOM	FERTILITY	SLOP	IMPSEED
LANDPOLICY	1						
SWC	-0.0232	1.000					
POVSTAT	-0.0139	0.0073	1.0000				
OFFINCOM	-0.0025	-0.027	-0.0195	1.0000			
FERTILITY	0.0373	-0.118	0.0496	0.0224	1.0000		
SLOP	-0.0187	-0.076	0.0544	-0.0009	0.1925	1.0000	
IMPSEED	0.0246	-0.107	0.1049	-0.0525	0.0696	0.0090	1.0000

Source: Own computation (2013)