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ANALYSIS OF FACTORS AFFECTING THE TECHNICAL EFFICIENCY OF COFFEE PRODUCERS IN JIMMA ZONE: A STOCHASTIC FRONTIER ANALYSIS

BY

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LIST OF ABBREVIATIONS AND ACRONYMS

GDP	Gross Domestic Product
MARD	Ministry of Agriculture and Rural Development
EASS	Ethiopian Agricultural Sample Survey
SAP	Structural Adjustment Program
ADLI	Agricultural Development Led Industrialization
IPRSP	Interim Poverty Reduction Strategy Paper
PRSP	Poverty Reduction Strategy Program
SDPRP	Sustainable Development And Poverty Reduction Program
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
EEA	Ethiopian Economic Association
GNP	Gross National Product
DRC	Domestic Resource Cost
TE	Technical Efficiency
FAO	Food and Agricultural Organization
CSA	Central Stastical Authority
DA	Development Agent
MLE	Maximum Likelihood Estimation
TLU	Tropical Livestock Unit
E.C.	Ethiopian Calendar
ML	Maximum Likelihood
LR	Likelihood Ratio
KG	Kilogram
SFA	Stochastic Frontier Analysis
GLS	Generalized Least Square
WLS	Weighted Least Square
VIF	Variance Inflation Factor
OLS	Ordinary Least Square
AERC	African Economic Research Consortium
DEA	Data Envelop Analysis
JZARD	Jimma Zone Agriculture and Rural Development

Abstract

Ethiopian coffee production and its productivity level are unsatisfactory to uphold the country's comparative advantage. The study intends to examine possible reasons for low productive performance of coffee using cross sectional data gathered from Jimma zone. An attempt to measure technical efficiency of coffee producers, analysis of its determinants and the impact of various distributional assumptions on technical efficiency estimates is made. Accordingly, both error component model and technical inefficiency effects model have been estimated in one step approach after data have been transformed. Maximum likelihood estimate of technical efficiency was obtained from truncated normal model which was supposed to describe the data adequately. The result revealed that various distributional assumptions of technical inefficiency have approximately similar impact of on TE estimates. On average, coffee producers are 72% efficient, implying that there is ample opportunity for these farmers to raise output level at present technology. There is also advantage of scale economies linked to increasing returns to boost output. Except fertilizer, overutilization of other inputs leads to inefficiency.

Technical inefficiency effects are modeled as a function of farmer specific socio-economic factors. Education, distance, family pressure and poor soil fertility tends to increase technical inefficiency of farmers whereas off farm income, proximity to market, cereal crop production, sex and good soil fertility improves their technical efficiency. Farmers can still produce higher output under available technology, indeed. Therefore, government should target at development of rural infrastructure, work diversification, rural employment creation, promotion of rural female management through awareness creation and soil conservation to overturn output loss by technical inefficiency of coffee producers in Jimma zone.

Chapter One: Introduction

1.1. Background of the Study

Ethiopia remains one of the poorest countries in the world in spite of its productive land, labor and natural resource. Human development indicators reveal that almost half of its population lives below poverty line. Agriculture which dominate Ethiopian economy, accounts for about half of GDP, 90% of exports, 85% of total employment. Consequently, Ethiopia stood third in the world and first in Sub-Saharan Africa in terms of the share of GDP that stems from agriculture Jema (2008).

Peasant farming is the most important in Ethiopian agriculture. Based on MARD (2008) report, more than 95 percent of the total viable agricultural land is cultivated by small holder peasant farmers that produce 97.6% of the agricultural output. In relative to most of African countries, except for oil and minerals, Ethiopia is taken as resource endowed country; falling in the top ten levels in Africa. Therefore, proper utilization of these resources might considerably improve the livelihood of the most populous smallholder resource-poor farmers Jema (2008).

To overturn poverty situations, the country set out a series of economic reform programs since 1991. The structural adjustment programme was introduced in 1991 with the aim of economic growth and poverty reduction. Following this the country has adopted agricultural development led industrialization (ADLI) strategy in 1993, Interim Poverty Reduction Strategy Paper (IPRSP) in 2000, Sustainable Development and Poverty Reduction Program (SDPRP) in 2002. All these strategies in collaboration with SAP were intended to bring about economic growth through increase in agricultural productivity. The above strategies were primary focused up on the poverty reduction.

In 2005 a plan for Accelerated and Sustained Development to End Poverty (PASDEP) was introduced. This strategy primary aims in the promotion of small scale market oriented agriculture which goes beyond poverty reduction. The country adopted such strategies to bring about improvement in agricultural sector, which is back bone of the economy; in fact, very little has been observed towards productivity improvement over past decades Author calculation based on EASS (1990-2008). As a result, to improve economic growth of the country, productivity growth of agriculture is inevitable. Despite substantial attempt on part of government to commence technological improvement in agriculture, the reason why the productivity of the agricultural sector is so low remains a challenge in the road towards agriculture based economic growth.

Economists argue that the achievement of (greater) efficiency from scarce resources should be a major criterion for priority setting especially in developing agricultural economies. In line with this, for the short run, many researchers have proposed technical efficiency improvement as a solution for the productivity problem through better information, credit provision, extension visit and education. Some of those studies include Alemu et al. (2009); Tsegaye et al. (2004); Weir and Knight (2004); Tassew et al. (2004); Getu et al. (2005); Seyoum et al. (1998); Jema (2008). To them, farmers can still produce maximum possible output from fixed set of inputs under the present technology. Given the above arguments, the overall objective of this technical efficiency measurement here is to create a sectoral atmosphere likely to improve coffee farm productivity, one of very important crop in Ethiopia.

1.2. Statement of the Problem

Coffee and Khat (chat) are Ethiopia's most important export crops. Currently, Coffee in Ethiopia accounts for more than 25% of GNP, 40% of the total export earning, 60% of agricultural export, 10% of the total government revenue and about 25% of the total population of the country are dependent on production, processing, distribution, and export of coffee MARD (2008). Moreover, the evaluation of the comparative advantage of coffee export crops among African countries revealed low domestic resource cost (DRC) for Ethiopian coffee relative to other African countries Pearson et al. (2007). The low DRC value of Ethiopian coffee relative to other indicates that Ethiopia has a more significant comparative advantage in coffee production. Consequently, coffee is a very important crop deserving particular attention in the context of development policies concerning agricultural exports and domestic resources allocation. Nevertheless, Ethiopian has not yet exploited its comparative advantage in coffee production although coffee plays significant role in Ethiopian economy Nicolas Petit (2007).

Yet, Ethiopian coffee production and its productivity level are not satisfactory that could uphold the country's comparative advantage. Although both number of coffee producers and area under coffee production have been increasing from time to time, the average productivity of coffee production in Jimma zone is below average productivity of coffee in Ethiopia EASS (2003-2008). Moreover, coffee production in Jimma zone is further showing high fluctuations than any other coffee producing zones in Ethiopia EASS (2003-2008). Hence, number of empirical studies is needed in Ethiopian context in order to improve the productivity of this very important crop in one way or another.

Following Schultz (1964) policy conclusions on traditional agriculture that no productivity could be achieved by reallocating resource at farmers' disposal, Ethiopian government can enhance production and its productivity level through technological innovation[1]. However, Ethiopian government in attempt to increase agricultural productivity through increased use of improved technologies has proved not to bring about the expected productivity gains in short run. This might be due to lack of the necessary technical skills and knowledge in using these technologies, poor extension and credit services, low rate of technological adoption and poor infrastructure and its relative cost among others Seyoum (1998); Tsegaye (2004). In fact, productivity increases not only depend on technological adoption only but also farmers' technical efficiency improvement.

In a country where resource constraint is the main problem of economic development and the rate of technological adoption is low, technical efficiency improvements in coffee production seems to be more advantageous. Therefore, measuring the resource use inefficiency, identifying factors that affect it and designing appropriate policies for mitigating the impediments may be more important and less costly than trying to introduce improved technologies. Furthermore, farmers' technical efficiency improvement facilitates long run rate of technological adoption and its effectiveness. So, technical efficiency study may be given priority before launching the technological advancement. Technical efficiency improvements as a solution can only be realized if the sources of inefficiency are identified well Coelli (1995), however.

A large number of studies on farm productivity in Ethiopia from different regions and sectors found that inefficiency exists (Alemu et al. (2009); Tsegaye (2004); Weir and Knight (2000); Getu (2005); Seyoum, Battese & Fleming (1998); Jema (2008); Nega et al. (2006)). Moreover,

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[1] *Technological adoption in coffee production could be in form of introduction of new plantations by removing the old coffee trees, introduction of new, improved machineries and instruments used in coffee production and the like.*

evidence from Seyoum et al. (1998); Getu (2005); Jema (2008), Tsegaye (2002) show that significant gain could be achieved in short run through resource reallocation at farmers' disposal. Nevertheless, these previous studies focused on the study of technical efficiency of other cereal crops and thus with little attention to the analysis of technical efficiency of coffee producers in Ethiopia. Therefore, in this study an attempt will be made to consider if coffee productivity in the Southwestern part of Ethiopia, Jimma zone, can be increased through creation of sectoral atmosphere likely to improve the technical efficiency of coffee producers and thereby improve coffee productivity.

1.3. Objective of the Study

The main objective of the study is to identify factors affecting the level of technical efficiency of coffee producers and its implication for increased productivity of coffee producers in Jimma zone. The specific objectives are:

1. Estimate the level of farmer-specific technical efficiency of coffee producers in Jimma zone
2. Identify and analyze the socio-economic variables affecting technical efficiencies of coffee producers in Jimma zone
3. Assess the impact of various distributional assumptions on technical efficiency level of each farmer and compare estimation results for the technical efficiency.

1.4. Hypothesis of the study

On the basis of the literature reviewed, the following null hypotheses were formulated for the above objectives so as to guide the study: -

Hypothesis 1: The first hypothesis is concerned with selection of appropriate functional form that describes the data set adequately. So, in this study it is hypothesized that Cob-Douglas production function describes the data adequately or Trans log production function is not an adequate representation of the data.

Hypothesis 2: Coffee producers in Jimma zone are technically efficient and no production loss is attached to technical inefficiency of coffee producers.

Hypothesis 3: The third null hypothesis for this study states that variables included under the inefficiency effects model are not jointly affecting technical inefficiency of the farmers in Jimma zone. Meaning that; age, educational level and experience of farmers, gender of house hold head, proximity to market, distance, number of livestock owned, membership in a social organization, population pressure, agricultural extension workers' contact with coffee producers, accessibility to credit, use of the coffee improved variety, and the practice of mono cropping do not significantly influence the farmer's technical inefficiency.

1.5. The Scope of the Study

The most important motivation for production improvement in most developing countries is need to raise productivity through technical efficiency, where resource constraints is of major problem, that also increases effectiveness of technological adoption in long run. Therefore, to attain such objective an empirical study is required to analyze technical efficiency of farmers. Having such insight, the focus is being placed on matured coffee owners of Jimma zone, the third most producers of coffee in Ethiopia. The focus on Jimma zone is being motivated from the fact that production of coffee is subjected to high fluctuations in relative to other zones of Ethiopia producing coffee crop EASS (2003-2008). Moreover, evidence from many empirical finding shows that efficiency study may be given priority setting in case where production reveals high fluctuations provided that productivity is relatively lower. Given resource at hand and reasons stated, therefore, the study is delimited to sample size of 150 matured coffee owners in Jimma zone during the period of 2008/9 coffee season.

1.6. Significance of the Study

Ethiopian agriculture is characterized by obsolete technology. This is expected to worsen productivity of the agricultural sector. In fact, technical inefficiency improvements can convey productivity gain at least for the short run. Thus, the country can benefit much from inefficiency studies that imply the possibility of developing the new technologies and prompt adoption of new technological innovation towards agricultural sector and consequently improve the level of productivity of farmers especially in short run. Identifying sources of inefficiency indicate which aspects of farm characteristics can be addressed by public investment to improve efficiency. Thus the results of this study are expected to give appropriate implications designed to increase agricultural productivity by identifying key sources of inefficiencies. The important implications are expected to capture an important environmental issue. Better flexibility in model specification under different assumptions of inefficiency (Truncated normal, exponential and half normal) and production function (Cobb-Doulas and/or Trans log) enable analyzing a given data using statistically sound techniques.

From micro economic point of view, technical efficiency improvements of farmers do have both long run and short run effect. If sources of inefficiencies are well identified, the government could improve the level of productivity of the zone and hence the profitability of the farmers given information driven from this study. The level of technical efficiency and the rate of technological adoption have direct relationships. Short run technical efficiency improvement could lead to long run productivity improvement of the zone since it facilitate for technological adoption and its effectiveness. Government could implement long run project when the producers of the zone are technically efficient. In fact, very little attention has been given to evaluate the technical efficiency level of coffee producers in Jimma and Ethiopia as well. The results of this study may fill this gap.

1.7 Organization of the Study

The rest of the thesis is organized in to four chapters. The analytical foundation of theoretical and empirical literature of efficiency measurements are well discussed in the chapter two. Following this, chapter three discusses about data and methodology. Whereas, chapters four is being devoted to results and discussions based on the theoretical and empirical foundations discussed in the chapter two and three. Finally, the last chapter concludes and stressed the policy implications based on the findings.

Chapter Two: Literature Review

2.1. Theoretical Literature

2.1.1. Definitions of Efficiency

Decision makers are increasingly faced with the challenge of reconciling growing demand for agricultural output and low agricultural production in developing countries. Efficiency measures whether resources (in the form of labor, capital, or equipment, etc) are being used to get the greater output. Adopting the criterion of economic efficiency implies that society makes choices which maximize the outcomes gained from the resources allocated. Inefficiency exists when resources could be reallocated in a way which would increase the outcome produced.

Technical efficiency refers to the physical relation between resources and outcome. A technically efficient position is achieved when the maximum possible improvement in outcome is obtained from a set of inputs. An intervention is technically inefficient if the same (or greater) outcome could be produced with less of one type of input. Technical efficiency cannot, however, directly compare alternative interventions, where one intervention produces the same (or better) outcome with less (or more) of one resource and more of another. *Torgerson and Palmer* (1999).

The concept of allocative efficiency takes account not only of the productive efficiency with which resources are used to produce outcomes but also the efficiency with which these outcomes are distributed among the community. Such a societal perspective is rooted in welfare economics and has implications for the definition of opportunity costs. In theory, the efficient pattern of resource use is such that any alternative pattern makes at least one person worse off. In practice, strict adherence to this criterion has proved impossible. Further, this criterion would eliminate as inefficient changes that resulted in many people becoming much better off at the expense of a few being made slightly worse off. *Ibid* (1999)

The first analyses of efficiency measures were initiated by *Farrell* (1957). He proposed a division of efficiency into two components: technical efficiency, which represents a firm's ability to produce a maximum level of output from a given level of inputs, and allocative efficiency (termed as price efficiency in work of Farrell), which is the ability of a firm to use inputs in optimal proportions, given their respective prices and available technology. The combination of these measures yields the level of economic efficiency (which was given a name of overall efficiency by Farrell).

Graphically based on Farrell (1957), measure of technical efficiency can be obtained by using input and output quantity without introducing prices of these inputs and outputs. He illustrated the meaning of efficiencies using figure1. Accordingly, observation P utilizes two input factors to produce a single output. SS' is the efficient isoquant estimated with an available technique. Now point Q on the isoquant represents the efficient reference of observation P. The technical efficiency of a production unit operating at P is most commonly measured by the ratio *Farrell* (1957)

$$TE = OQ/OP \qquad (2.1)$$

Technical efficiency value will take a value between zero and one, and hence an indicator of the degree of technical inefficiency of the production unit. A value of one indicates the firm is fully technically efficient. For instance, the point Q is technically efficient because it lies on the efficient isoquant.

If the input price ratio, represented by the slope of the isocost line, AA' in figure 1, is also known, allocative efficiency may also be calculated. The allocative efficiency (PQ') of a Production unit operating at P is defined to be the ratio $Farrell$ (1957)

PQ'=OR/OQ (2.2)

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

EE=OR/OP (2.3)

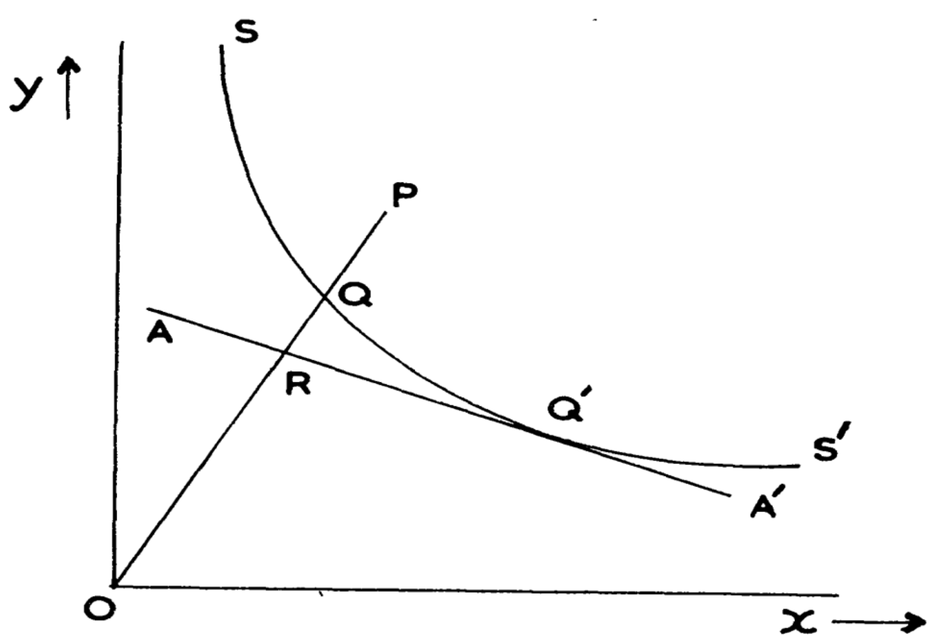


Figure 1 Technical, Allocative and Economic efficiencies Farrell (1957)

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

2.1.2. Techniques of Efficiency Measurement

Efficient frontier represents set of maximum output (potential output) for a given set of scarce resource and risk associated with it Farrell (1957). In order to measure technical efficiency we must construct efficient frontier. Two main approaches are used to construct efficiency frontiers, parametric and non parametric approaches. In non parametric approach, estimation methods are based on envelopment techniques, free disposal hull which is developed by $Deprins\ et\ al.$ (1984) and data envelopment analysis which is developed by $Farrell$ (1957). In both methods the estimation of technical efficiency is based on linear programming and consists of estimating a production frontier through a convex envelope curve formed by line segments joining observed efficient production units. No functional form is imposed on the production frontier and no assumption is made on the error term. However, this method has disadvantage over: firstly, one cannot test for the best specification; secondly, it does not take measurement errors and random effects into account (it supposes that every deviation from the frontier is due to the firm's inefficiency); thirdly, the number of efficient firms on the frontier tends to increase with the number of inputs and output variables and fourthly, results are sensitive to the selection of inputs and outputs.

The second approach, on the other hand, is called parametric approach. The stochastic frontier production function estimation would depend on this approach. It was independently and simultaneously proposed by $Aigner\ et\ al.$ (1977)and M$eeusen\ and\ Van\ dan\ Broeck$ (1977).

Unlike envelope analysis, the stochastic frontier approach enables us: one, we can test for the best specification; two, it takes measurement errors and random effects into account (composed error approach). Thus deviation from efficient frontier is not only measurement error but also management inefficiency. In contrast to the envelop analysis, this approach depends on econometric estimation procedure.

The stochastic frontiers method is used in this study. This choice was made on the basis of the variability of agricultural production, which is attributable to climatic hazards, plant pathology and insect pests, on the one hand, and, management inefficiencies on the other. In fact, the stochastic frontiers method makes it possible to estimate a frontier function that simultaneously takes into account the random error and the inefficiency component specific to every plantation Amadu Nchare (2007). Critical review of parametric approach to efficiency measurement will be discussed in the sections 2.1.4 with various distributional assumptions of u_i that helps us to segregate technical efficiency indicator from composed error term.

2.1.3. Approaches for Identifying and Analyzing Determinants of Technical Efficiency

There are two main approaches that help to examine determinants of technical efficiency from stochastic production function. Namely, one step approach and two step approach. In the two step approach, we first estimate the error component model from stochastic frontier function to determine technical efficiency indicators. Subsequently, technical inefficiency thus obtained are regressed on explanatory variables that usually represent the firms' specific characteristics (Technical efficiency effect model), using the ordinary least square (OLS) method. In this approach, the value of technical efficiency estimate is predicted using $Jondrow\ et\ al.$ (1982) procedure.

However, this approach has major shortcoming emanate from inconsistency that could be created from the assumptions related in the distribution of u_i in the estimation of technical inefficiency effect model and error component model. In the estimation of error component model, technical inefficiency of farmer i (u_i) are assumed to be normally, independently and identically distributed. However, the technical inefficiency indicators thus obtained are assumed to have one side distribution (i.e. $u \geq 0$) Coelli (1995) unless all the coefficients of the factors considered happen to be simultaneously zero.

The second approach called one step approach come to exist after independent and simultaneous work of Kumbhakar et al. (1991) and Reifschneider and Stevenson (1991). To them inconsistency is being created between error component model and technical efficiency effect model of stochastic frontier estimation and in identifying factors affecting technical efficiency indicators. They developed a procedure in which all parameters are estimated using maximum likelihood procedure. In similar to two step approach, one step approach follows similar step in identifying factors affecting technical efficiency of farmers. Nevertheless, unlike the OLS method, Maximum likelihood would assume the same assumptions for distribution of u_i in estimation of stochastic production frontier and u_i which will be regressed up on the determinants of technical efficiency. Yet, from the characteristic of likelihood function it is difficult to identify local maximum as long as there are many ups and downs Coelli and Battese (1996).

In the one-step approach, the error component model and Technical efficient effect models are estimated in one step maximum likelihood estimation approach. Technical efficiency effect model according to *Coelli and Battesse* (1996) is specified as ($u_i = \delta z_i + w_i$). Where u_i is vector of farmer specific technical efficiency calculated using MLE, z_i is the vector of factors affecting technical efficiency of specific farmer i**,** δ is a vector of parameters to be estimated, and w_i is the random terms assumed to be independently and identically distributed. It is defined by the truncation of the normal distribution with zero mean and unknown variance δ_w^2 such that $u_i$is one sided distribution (non negative) $Coelli$ (1995).

This study used the one-step approach provided that one step approach has an advantage of being less open to criticism at the stastical level that would have been occurred if two step approach is being under taken. Moreover, this approach enables us to test hypothesis on structure of production function and output of final efficiency score without additional programming simultaneously. The following section reviews methods of efficiency measurement, comparison, strength and weakness

2.1.4. The Econometric Approach to Efficiency Measurement

It is parametric approach used to measure technical efficiency from the stochastic production frontier. The assumption here in estimating production frontier is that all farmers in the sample use the same technology. The data underlying the study consist of observations on the quantities of inputs employed and the output provided by each farmer for the maintenance of matured coffee trees only. Since coffee is of long gestation period, factors of production employed capture of those that farmers applied for the maintenance of matured coffee trees during the last coffee season.

Moreover, output oriented measure of technical efficiency was applied in this study. Based on the specification of $Jondrow\ et\ al.$ (1982) the stochastic production function for the cross-sectional data can be written as follows

$$Yi = f(Xi;\ \beta).TEi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.4$$

Where Y_i is the scalar output of producer i, $i = 1, \ldots, N$, Xi is a vector of K inputs used by producer $i, f(Xi;\ \beta)$ is the stochastic production frontier, β is the parameters to be estimated, and TEi is the output-oriented technical efficiency of producer *i.* Hence based on the equation 2.4 technical efficiency, which is also supposed to have stochastic distribution, of specific farmer can be derived as $Aigner\ et\ al.$ (1977)

$$TEi = \frac{Yi}{f(Xi;\beta)}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.5$$

The equation 2.5 reveals that technical efficiency is the ratio of observed output to frontier output (maximum output feasible under the current technology used). Yi achieves' its maximum value if and only if $TEj = 1$. Technical inefficiency occurs when $TEi < 1$. Frontier function in an econometric model is classified as either *deterministic frontier model* or *stochastic frontier model* according to assumptions about the composed error term and the way that inefficiency is defined $Coelli$ (1995). In equation (2.4) the production frontier $f(xi;\ \beta)$ is deterministic. This is so because the deterministic frontier would take factors outside the control of the unit, such as bad weather, uncertainties in the market situation and so on as inefficiency, any error or imperfection in the specification of the model is indication of technical inefficiency. Nevertheless, the stochastic production frontier comprised composed error term (technical inefficiency and random shock outside control of farmers). According to $Aigner\ et\ al.$ (1982) the stochastic frontier can be written as

$$yi = f(xi;\ \beta).exp\{vi\}.TEi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.6)$$

With this specification TE for the specific farmer, which also expected to take stochastic distribution, can be derived based on the work of *Aigner et al.* (1982) and *Coelli* (1995) as

$$TE = \frac{Yi}{f(Xi;\beta).\exp\{Vi\}'} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.7)$$

This is output oriented technical efficiency measure that is the ratio of observed output (Yi) to maximum feasible output. Even though both deterministic and a stochastic production frontier function helps to estimate technical efficiency score for each farmer under consideration, deterministic frontier *Aigner et al.* (1982) is less flexible and the inefficiency score resulted is entire outcome of deviation from frontier production function and it does not recognize composed error term. Having understood this in literature, an attempt was made to specify production frontier in form of stochastic function. This is more flexible than deterministic approach *Aigner et al.* (1977). Therefore this paper uses the stochastic production frontier specification, in which error term is expected to have stochastic distribution, identically and independently distributed to each other, and the mean of inefficiency indicator is derived at truncation of zero mean and δ_u^2 variance *Jondrow et al.* (1982) and *Coelli* (1995).

2.1.5. The Stochastic Production Frontiers Approach

The stochastic production frontier is motivated by the idea that deviations from the production frontier may not be entirely under the control of the production unit under study. These models allow for technical inefficiency, but they also acknowledge the fact that random shock outside the control of producers such as effects of weather, luck, etc. The main virtue of stochastic frontier models is that at least in principle these effects can be separated from the contribution of variation in technical efficiency *Aigner, Lovell and Schmidt* (1977).

Following the specification by $Aigner\ et\ al.$ (1977) and $Coelli$ (1995) the stochastic production frontier model for i[th] production unit can be specified as

$$Yi\ =\ f(xi,\beta) + Vi\ - Ui;\ =\ f(xi,\beta) + \varepsilon i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..2.8$$

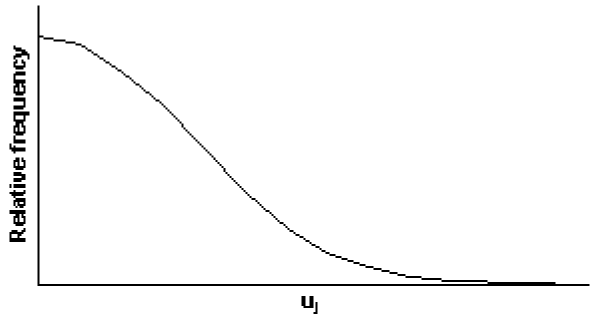
Here the stochastic production function has composed error. Where V_i is noise component which captures deviation from stochastic production frontier due to outside control of farmers, and Ui is the non negative technical inefficiency component of the error term. The noise component Vi is assumed to be independently and identically normally distributed (iid) and distributed independently of u. Thus the error term $\varepsilon i = Vi\ - Ui$ is not symmetric, since $u\ \geq\ 0$. Assuming that $Vi\ and\ Ui$ are distributed independently of *xi*, estimation of (2.8) by Ordinary Least Square (OLS) provides consistent estimates of the parameters except $\beta 0, since\ E(\ \varepsilon\ ) = -E(u) \leq 0\ since\ by\ defintion\ E(V) = 0.$

In estimating stochastic production frontier, technical inefficiency indicator, u for each farmer must be identified. To achieve this objective separation of v and u *are* required from estimates of εi for each producer. However, in order to separate this composed error term from each other, it requires one distributional assumption on the two error components besides the estimation techniques and tools like Limped 8.0 and Frontier 4.1. Though corrected OLS and discrete choice variable model can estimate technical efficiency, the result could be inconsistent due to violation of assumption of composed error term. In order to separate the v and u from stochastic production function model, a distributional assumption has to be made for $u_i\ Jondrow\ et\ al.$ (1982). Based on literature review, we have four assumptions for the distributions of technical inefficiency indicator (u_i), namely, half normal, truncated normal, exponential and gamma.

There are no *a priori* reasons for choosing one distributional form over the other, and all have advantages and disadvantages FAO (2003). For example, the exponential and half-normal distributions have a mode at zero, implying that a high proportion of the firms being examined are perfectly efficient. The truncated normal and two-parameter gamma distribution both allow for a wider range of distributional shapes, including non-zero modes. However, these are computationally more complex FAO (2003). Empirical analyses suggest that the use of the gamma distribution and exponential distribution is more or less similar and thus one can use either of the two with minor difference $Tewodros$ (2001). Different literature propose that distributional assumptions which allows higher proportion of the sample operating at higher level of efficiency levels are exponential, half normal and truncated normal respectively $Coelli$ (1995). Nevertheless, half normal and truncated normal distribution for technical efficiency indicator is preferable for empirical analysis.

2.1.5.1. The Normal-Half Stochastic Frontier Model

Normal half stochastic frontier model was first discussed by $Jondrow\ et\ al.$ (1982). Thus in this section discussion is entirely based on their work. According to $Jondrow\ et\ al.$ (1982) half normal distribution has mode at zero implying that high proportions of farmers being examined are technically efficient. The proportion of low technically efficient farmers is low relative to other two distributions although case of exponential distribution is too low. Based on $Jondrow\ et\ al.$ (1982) half normal stochastic frontier model, we make the following assumptions for composed error term. One, $Vi \sim iid\ N\ (O,\ \delta_v^2)$; two, $ui \sim\ iid\ N^+$ (0, δ_u^2), that is nonnegative half normal; three, $Vi\ and\ Ui$ are distributed independently of each other and of the regressors.



$TE = e^{-uj}$

Figure 2 Normal- half distributions FAO (2003)

The separation of composed error term is done based on their density function. The density function of $u \geq 0$ for the case of half normal following *Jondrow et al.* (1982) is given by

$$f(u) = \frac{2}{\sqrt{2\Pi\delta u}} \exp\left\{-\frac{u^2}{2\delta_u^2}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.9$$

The density function of *v* following (Jondrow et al, 1982) is

$$f(v) = \frac{2}{\sqrt{2\Pi\delta v}} \exp\left\{-\frac{v^2}{2\delta_v^2}\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.10$$

Given u and v are independently distributed, the joint density function of *u* and *v following* *Jondrow et al.* (1982) is the product of their individual density functions and is given as

$$f(u, v) = \frac{2}{2\Pi\delta_u\delta_v} \exp\left\{-\frac{u^2}{2\delta_u^2} - \frac{v^2}{2\delta_v^2}\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.11$$

Since $\varepsilon = v - u$, the joint density function of u *and* ε is

$$f(u, \varepsilon) = \frac{2}{\sqrt{2\Pi}\,\delta u\delta v} \exp\left\{-\frac{u^2}{2\delta_u^2} - \frac{(\varepsilon + u)^2}{2\delta_v^2}\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.12$$

The marginal density function of ε *following Jondrow et al.* (1982)*:* is obtained by integrating *u* out of $f(u, \varepsilon)$ which yields

$f(\varepsilon) = \int_0^{\infty} f(u,\varepsilon)du$

$$= \frac{2}{\sqrt{2\Pi}\,\delta}\left[\left(1 - \phi(\frac{\varepsilon\lambda}{\delta})\right)\right] \exp\left\{-\frac{\varepsilon^2}{2\delta^2}\right\} \ldots\ldots 2.13$$

$$= \frac{2}{\delta} \cdot \phi\left(\frac{\varepsilon}{\delta}\right) \cdot \Phi\left(-\frac{\varepsilon\lambda}{\delta}\right)$$

Where $\delta = (\delta_u^2 + \delta_v^2)^{1/2}$, $\lambda = \frac{\delta_u}{\delta_v}$ and $\Phi\,[.]$ *and* $\phi\,[.]$ are the standard normal cumulative distribution and density functions. The marginal density function *f (ε)* is asymmetrically distributed, with mean and variance based on the work of *Jondrow et al.* (1982).

$$E(\varepsilon) = -E(u) = -\delta_u\sqrt{\frac{2}{\Pi}}$$

$$V(\varepsilon) = \frac{\Pi - 2}{\Pi}\delta_u^2 + \delta_v^2 \ldots\ldots 2.14$$

The normal-half normal distribution contains two parameters, δu *and* δy *Aigner, Lovell and Schmidt* (1977) suggested $[1 - E(u)]$ as an estimator of the mean technical efficiency of all producers. However, *Jondrow et al.* (1982) proposed mean technical efficiency to be

$$E(\exp\{-u\}) = 2\left[1 - \phi(\delta u)\right] \cdot \exp\left\{\frac{\delta_u^2}{2}\right\} \ldots\ldots 2.15$$

Moreover, unlike $[1 - E(u)]$, $E(exp\{-u\})$ is consistent with the definition of technical efficiency given in equation (2.7). The log likelihood function for a sample of N producers *Jondrow et al.* (1982) is

$$\text{LnL} = -\left(\frac{N}{2}\right)\left(ln2\Pi + ln\delta^2\right)\sum_i\left[ln\Phi\left[-\varepsilon i\frac{\lambda}{\delta}\right] - \frac{1}{2}\left(\frac{\varepsilon i}{\delta}\right)^2\right] \ldots\ldots\ldots\ldots\ldots 2.16$$

Log likelihood and likelihood function is similar. Given the above, the frontier parameters would be obtained by taking first order condition. These estimates are consistent as sample size tends to infinitive. However mean of (u_i) is summary measure and it is not an indication of technical efficiency of each farmers. Thus, we must decompose the technical inefficiency conditional up on composed error term (e_i) $Jondrow, Lovell\ and\ Schmidt$ (1982). Following similar work, the density function of u_i conditional up on the e for the normal half distribution showed that if $ui \sim N^+ (0, \delta_u^2)$ is

$f(u/\varepsilon) = f(u, \varepsilon)/f(\varepsilon)$

$$= \frac{1}{\sqrt{2\Pi}} \cdot \exp\left\{-\frac{(u-\mu*)^2}{2\delta_*^2}\right\} / \left[1 - \Phi\left(-\frac{\mu*}{\delta*}\right)\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.17$$

Where $\mu * = -\varepsilon\frac{\delta_u^2}{\delta\char`^2}$ and $\delta* = -\varepsilon\frac{\delta_u^2\delta_v^2}{\delta^2}$. Since $f\ (u\ (\varepsilon))$ is distributes as $N^+\ (u*, \delta_*^2)$, the mean of this distribution can serve as a point estimator of ui. Following (Jondrow et al, 1982) this is given by

$$E(ui/\varepsilon) = \mu * + \delta * \left[\frac{\phi(-\mu*\frac{i}{\delta}*}{1-\Phi(-\mu*\frac{i}{\delta}*}\right]$$

$$= \delta * \left[\frac{\phi(\varepsilon i\lambda/\delta}{1-\Phi(\frac{\varepsilon i\lambda}{\delta})} - \left(\frac{\varepsilon i\lambda}{\delta}\right)\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.18$$

Estimates of ui can be obtained from

$$TEi = exp\{-ui = exp\{-E(ui/\varepsilon i\}. \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.19$$

Based on the above formula, we can estimate technical efficiency of each farmer using Stata, Limdep and Frontier though frontier 4.1c can estimate this value without requiring additional programming.

2.1.5.2. The Exponential and Truncated-Normal Stochastic Frontier Models

Exponential and truncated normal stochastic frontier models are proposed by $Meuseen\ Van\ dan\ Broeck$ (1977) and $Aigner, Lovell\ and\ Schmidt$ (1977) respectively. Exponential distribution gives large proportion of firms as they are technically efficient. Turning to the stochastic production frontier model given in equation (2.8) two additional distributional assumptions, exponential and truncated-normal, can be made as; one, $ui\ \sim iid\ exponential$; two, $ui \sim iidN+\ (\mu,\ \delta_u^2\ )$ truncated normal; three, u and v are independently distributed. Even though the truncated normal and two-parameter gamma distribution both allow for a wider range of distributional shapes including non-zero modes, exponential distribution allows zero mode. Indicating large proportion of farmers are operating at efficient level.

Maximum likelihood estimation technique can be applied on the log likelihood functions of the joint distribution of v and u for both the exponential and truncated normal distributional assumptions. Reference on the functional properties of these models can be made on the recent literature by $Meuseen\ Van\ dan\ Broeck$ (1977). Following the work of $Meuseen\ Van\ dan\ Broeck$ (1977) for the case of exponential model technical efficiency of specific farmers can be calculated based on the following:

$$E(ui/\varepsilon i)\ =\ \delta v\left[\frac{\phi(A)}{\Phi(-A)}-\mathrm{A}\right]$$

Where $A = -\frac{\mu'}{\delta v}\ and\ \mu' = -\ \varepsilon - (\frac{\delta_v^2}{\delta_u})$. ……………………………………………….………………… (2.20)

For the truncated normal model, following the work of $Aigner, Lovell\ and\ Schmidt$ (1977) the estimate of mean technical efficiency of specific farmers can be obtained using the following formula specified by $Aigner, Lovell\ and\ Schmidt$ (1977) as

$$E(ui/\varepsilon i) = \delta * \left[\frac{\tilde{\mu}}{\delta *} + \frac{\phi(\frac{\tilde{\mu}}{\delta} *)}{1 - \Phi(-\frac{\tilde{\mu}}{\delta *})} \right]$$

Where $\tilde{\mu} = -\frac{\delta_{u\ \varepsilon}^2 + \mu \delta_v^2}{\delta^2}$ and $\delta_*^2 = \frac{\delta_u^2 \delta_v^2}{\delta^2}$ … … … … … . . … … … … … … … … … … … … … … … 2.21

The following graphs show distributions of u_i under the assumption of Truncated normal and exponential.

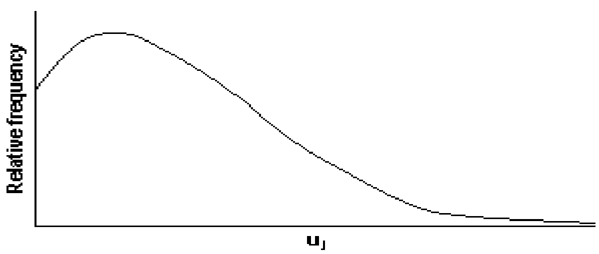


Figure 3 Truncated normal

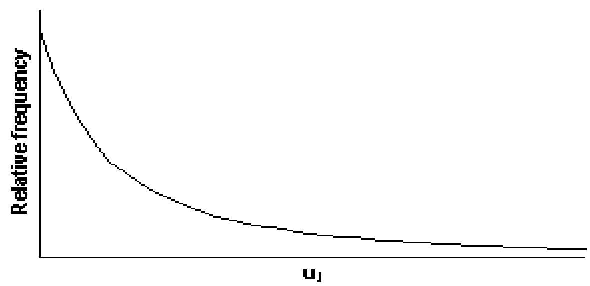


Figure 4 Exponential Distribution

According to $Greene$ (2000) normal gamma and exponential function has similar effect on technical efficiency estimation.

2.2. The Empirical Literature

By applying stochastic frontier one step approach $Battese\ and\ Coelli$ (1996) try to examine factors that influence the technical inefficiency of Indian farmers using panel data. The study estimated error component model and technical efficiency effect model using the soft ware called frontier 4.1c. Technical efficiency effect model shows that farm size, farmer’s age and educational level of farmers the main important determinants of technical efficiency of Indian farmers. The mean technical efficiency of those farmers were 0.73, 0.74 and 0.71 respectively, for the villages of Aurelle, Kanzara and Shirapur.

Similarly, the study on the factors affecting technical efficiency of Indian Paddy $Battese\ and\ Coelli$ (1995) found a positive relationship between the degree of inefficiency and the producer's age, and a negative relationship between the degree of inefficiency and the educational level of the producer. Following their work they concluded that government must give priority settings towards educational investment. However, their work is limited in excluding some important variables used in output and technical efficiency modeling like rainfall, access to credit, and agricultural extension service. The main advantage of their work is that they contributed significant work towards efficiency study as they are the first for technical efficiency study using one step approach using Frontier 4.1c developed by $Coelli$ (1996).

By using a stochastic frontier approach which is used to estimate an input distance function and evaluate production efficiency during the period 2005 $Cardena$ (2005) tries to estimate technical efficiency of coffee producers in Mexico. Factors such as coffee quality and access to markets are tested in terms of their effects on technical efficiency. Results show that the production process in these municipios, as measured by technical efficiency, appears to be stable over time despite price fluctuations in the global market. Production of staple crops (corn) along with coffee resulted in lower efficiency. Factors contributing to higher efficiency included higher population density, production of specialty crops other than coffee or staple crops, and higher altitude, which is typically associated with production of higher quality coffee. These findings can be then considered part of an effort that can be extended to contribute to creation of suitable policies focused at a regional or district level.

The study by Amadu Nchare (2007) tries to analyses of factors influencing the technical efficiency of Arabica coffee farmers in Cameroon. To carry out this analysis a Trans log stochastic production frontier function, in which technical efficiency effect model and error component models, is estimated using the one step maximum-likelihood method. The data used were collected from a sample of 140 farmers during the 2004 crop year. The results obtained show some increasing returns to scale in coffee production. The mean technical efficiency index is estimated at 0.896, and 32% of the farmers surveyed have technical efficiency indexes of less than 0.91. The analysis also reveals that the educational level of the farmer and access to credit are the major socioeconomic variables influencing the farmers' technical efficiency. The findings prove also that further productivity gains linked to the improvement of technical efficiency may still be realized in coffee production in Cameroon.

The paper by $Nyemeck\ et\ al.(2003)$ presents measures of technical efficiency for a sample of 81 peasant farmers in the low-income region of Cote d'Ivoire producing Robusta coffee. DEA techniques were used to compute farm-level technical efficiency (TE) measures. The analysis reveals average levels of technical efficiency equal to 36 per cent and 47 per cent respectively for the Charnes and Banker models. These results suggest that substantial gains in output and/or decreases in cost can be attained given existing technology. In a second step analysis, two-limit Tobit regression techniques were used to examine the relationship between TE and various farm/ farmer characteristics. The analysis suggests that policymakers should foster the development of the formal farmers' club or association by building the capacity of the farmers. Their analysis also supports the argument for public sector involvement in the provision of information on labor force management to peasant farmers as a means to improve efficiency levels, and thus household incomes.

The paper by $Seyoum\ et\ al. (1998)$ investigates the technical efficiency of two samples of maize producers in eastern Ethiopia, one involving farmers within the Sasakawa-Global 2000 project and the other involving farmers outside this program. The study uses stochastic frontier production functions in which the technical inefficiency effects are assumed to be functions of the age and education of the farmers, together with the time spent by extension advisers in assisting farmers in their agricultural production operations. The empirical results indicate that farmers within the Sasakawa-Global 2000 project are more technically efficient than farmers outside the project, relative to their respective technologies. For farmers still using traditional production methods, however, the level of education did not significantly affect technical efficiency. The mean frontier output of maize for farmers within the Sasakawa-Global 2000 project is significantly greater than that for the farmers outside the project.

The study by $Tassew\ et\ al. (2004)$ on technical efficiency of peasant farmers in northern Ethiopia, have chosen for the output-oriented or primal approach, where the central issue is by how much output could be expanded from a given level of inputs. The study applied one step approach of maximum likelihood estimation procedure in order to estimate error component model and technical efficiency effect model. Farmers in the sample are located particularly in *Enderta* and *Hintalo-Wajerat* districts of the Tigray region. A preliminary analysis showed that productivity differences among farmers are rather small (compared to other studies). Thus there is little room for the efficiency improvement as long as peasants are more efficient supporting Schultz's popular 'poor-but-efficient hypothesis'. There appears to be increasing emphasis by policy-makers on investments in new technologies and inputs rather than efforts aimed at improving the efficiency of less efficient farmers.

Study by Alemu and et al. (2009) tries to fill the gap by investigating efficiency variations and factors causing (in) efficiency across agro-ecological zones in East Gojjam, Ethiopia. Data were collected from 254 randomly selected households. Stochastic frontier production function was estimated and the results of the analysis revealed a mean technical efficiency of 75.68% (ranging from 32.15% to 92.66%). F-test also showed a statistically significant difference in technical efficiency among agro-ecological zones with highland zones scoring the highest leading to a rejection of the hypothesis of no significant efficiency difference. On the other hand, maximum likelihood estimates indicated positive and significant elasticities for inputs such as land, labor, draft power and fertilizer. Besides, education, proximity to markets, and access to credit were found to reduce inefficiency levels significantly. However, neither extension visits nor trainings on farmland management brought positive impacts in affecting the efficiency level of farmers. Thus, future endeavors may need to find ways to envisage better extension services provisions that are tailored to the peculiarities of the agro-ecological zones. Last but not least, improved market outlets and reduced liquidity constraints should be considered to change things for the better.

According to the study made by $Weir\ and\ Knight\ (2000)$ on the educational externality in rural Ethiopia in terms of potential size and source of benefits, education will have externality effects in agriculture if in the course of conducting their own private economic activities, educated farmers raise the productivity of uneducated farmers with whom they come into contact. Average and stochastic frontier production function methodologies are employed to measure productivity and efficiency of farmers using one step maximum likelihood procedure. In each case, internal and external returns to schooling are compared. They find that there are substantial and significant externality benefits of education in terms of higher average farm output and a shifting outwards of the production frontier. External benefits of schooling may be several times as high as internal benefits in this regard. However, they are unable to find any evidence of externality benefits to schooling in terms of improvements in technological efficiency in the use of a given technology. This suggests that the source of externalities to schooling is in the adoption and spread of innovations, which shift out the production frontier.

Chapter Three: Data and Methodology

3.1. Background of the Study Area

Jimma is one of the oldest zones in Ethiopia. It is bordered on the south by the southern nation, nationality and peoples region, northwest by Illubabor, on north by east Welega and in northeast by west shoa. Coffee and Khat is the main important cash crop of the zone. Based on EASS (2008) 55129529kg of coffee were produced in this zone in the year ending in 2008. This represents 23.2% of the Region's output and 11.8% of Ethiopia's total output, and makes Jimma one of the three top producers of this crop, along with the Sidama and Gedeo Zones. In fact, most kebeles found Jimma zone has potential of producing coffee crop.

Among seventeen woredas found in Jimma zone, Gomma, Limmu Kosa, Manna, limmu saqa and Gera produces altogether around 68 percent of coffee produced in zone. Large portion of these woredas are located in semi arid climatic conditions with altitude ranging between 1338 to 3000m above sea level. Plantation coffee and Garden coffee have large coverage in the zone, having 61.8% and 14.6% share respectively. Beside this, forest tree, semi-forest coffee and stumped coffee are also essential types of coffee in the zone. Moreover, the productivity of plantation coffee is the highest with stumped coffee following. However, forest coffee trees have lowest productivity among all types of coffee trees found in Jimma zone.

Based on figures from the CSA in 2007, this zone has an estimated total population of 2,773,730, of whom 1,382,460 are men and 1,391,270 are women; 2,432,562 or 87.7% of its population are rural dwellers. With an estimated area of 18,412.54 square kilometers, Jimma has an estimated population density of 150.64 people per square kilometer. Evidence from JZARD shows us that five largest ethnic groups reported in Jimma were the Oromo (81.57%), the Yem (5.28%), the

Amhara (4.95%), the Kullo (2.9%), and the Kafficho (1.78%); all other ethnic groups made up 3.52% of the population. The majority of the inhabitants were Muslim, with 82.57% of the population having reported they practiced that belief, while 15.78% of the populations are orthodox, and 1.47% follows protestant.

Evidence from JZARD further shows that the average rural household has 0.9 hectare of land (compared to the national average of 1.01 hectare of land and an average of 1.14 for the Oromiya Region) and the equivalent of 0.5 heads of livestock. 25.1% of the population is in non-farm related jobs, compared to the national average of 25% and a Regional average of 24%. Concerning education 57% of all eligible children are enrolled in primary school, and 12% in secondary schools.

3.2. Data source and Sampling Design

3.2. 1. Sources of Data

In order to analyze factors affecting technical efficiency of coffee producers in Jimma zone both primary and secondary sources of data were used. To attain the stated objectives, both data on the technical coefficients (inputs–outputs) of coffee production and socioeconomic characteristics of farmers were collected. The data collected include all factors of production (i.e. land, labor, fertilizers, capital and age of coffee trees) used in coffee production, coffee yield, output sold, transport and marketing costs. The inputs enumerated are those type of inputs used in production and maintenance of matured coffee trees in Jimma zone. In fact, the application of chemical fertilizer, pesticides and herbicides to matured coffee trees was prohibited since Derg regime in Ethiopia. As a result, the observed technical input coefficient excludes these inputs. All data on technical coefficients were gathered using structured questionnaire that is filled by well trained enumerators.

The socio-economic characteristics, which are supposed to explain technical inefficiency of coffee producers, were gathered from farmers who owned matured coffee trees in Jimma zone. The socio economic factors included in explaining technical inefficiency of coffee producers in this study are: producer age, level of education of household head, experience of household in coffee production, population pressure, extension contact, proximity to market, distance from home to coffee plot, system of cropping, access to credit, sex of household head, soil fertility, membership in local organizations and the slope of the plot.

Those household head who owned matured coffee trees during the period 2008/9 in Jimma zone are considered as the sampling unit of the study. The data were gathered the moment coffee harvesting is over so that the farmers are able to memorize all information they are asked during survey. As far as secondary sources of data is concerned, the data were collected from Central Stastical Authority, Ministry of Agriculture and rural development of Ethiopia, and Agriculture and Rural development of Jimma zone.

3.2.2. Sampling Design

Jimma zone has seventeen woredas. Namely, Dedo, Gera, Gomma, Kersa, Limmu Sakka, Limmu Kosa, Manna, Omo Nada, Saka Chekorsa, Setema, Sigmo, Sokoru, C/Batar, Sanxama, N/ Benja, Guma and Tiro Afeta. Coffee is very important cash crop in all Woredas of the zone except Sigmo woreda. Given the resources, five woredas of the zone namely; Gera, Gomma, Limmu Saka, Limmu Kosa and Manna, were selected through purposive sampling. These woredas were selected based on their importance (their contribution) in coffee production to the zone. As a whole, these five woredas contributed 68 per cent of total coffee production of the zone.

Accordingly, the total sample size used for this study was 150 farmers that own matured coffee trees. In this respect, non proportional sampling technique has been adopted to distribute this sample size across five woredas being selected. The sample size allotment across each woredas selected was done based on the data from Jimma zone agriculture and rural development. Data on the level of total coffee production for each woredas over time and the number of coffee owners were used for the computation. The detail of sample selection procedure is given in table 1. Once the woredas are selected, the selection of kebeles[2] for the survey was done using the convenience sampling method. This is because of the fact that all kebeles in these woredas produce coffee and contribute significant figures in total Woreda coffee production. As a result, the selections were carried out in collaboration with Jimma zone coffee production expert and DA's of respective woredas who settled around production area.

After the kebeles are drawn based on convenience sampling they have been merged to get sampling frame for each woredas. Then final sample units were selected by applying systematic random sampling to the sampling frame of respective woredas until the required number of sample size allocated to each woredas fill up. In case the sample drawn becomes household head who own unmatured coffee, the sample will be repeated to get target households with matured

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[2] *For the purpose of this study particular kebeles considered for this study are Hunda Toli and Buture from Manna Woreda;Ceesoo kebele from Gera Woreda; Keelaa Gabisa, Acaa and Arangama from Limmu Kosa woreda; Koomaa and Saqqaa from Limmu Saqa and Koyee Seja, beeroo and tuphaan from Gomma woreda*

coffee. This is due to the fact that the objective of this paper is to analyze the technical efficiency of farmers with matured coffee trees.

However, woredas differ not only in size but also in variability of coffee output. In this case it is reasonable to take larger samples from woredas with higher variability of coffee output and smaller sample from the less variable woreda. This is because by considering variability of coffee output you can account for both differences in size and woreda's coffee output variability. In view of that, disproportionate sampling design has been adopted for this study provided that Jimma zone is characterized with high variability in coffee production. Although the design does not give attention for size of the population of the woreda, it may helps to study the main cause behind coffee output variability as it attaches larger size to places where coffee output fluctuation is high.

To get the final sample size for the survey the formula developed by Snedecor and Cochrane (1980) was used. Accordingly,

$$n_h = n * \frac{N_h S_h}{\sum N_h S_h} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 3.1$$

Where; n_h is the sample size per woreda and n = 150 is the total sample size planned to be covered. N_h is the number of coffee producers in woreda h, and S_h is the standard deviation of coffee output per farm in woreda h. See the details of the distribution of sample coffee producers per woreda h in the table 1.

Table 1 Distribution of Sample households per Woreda

Zone	Woreda name	No. of coffee owners	Standard deviation	N_hS_h	Sample size per woreda (n_h)
Jimma	Manna	30540	2109.32	64418511	39
	Limmu Saka	14804	1485.43	21990365	13
	Limmu Kosa	24893	2629.22	65449149	40
	Gera	16229	1039.8	16874979	10
	Gomma	30000	2644.07	79322190	48
	Total	116466	9907.85	248055193	150

Source: Author compilation based on the data from Agriculture and rural development of Jimma zone using equation 3.1

3.2.3. Data Quality Control and Questionnaire Organization

Effort have been put in each activity of the sample to assure data quality. Ample time has been given in order to prepare questionnaire very well in such way that the enumerators can easily understand it. The questionnaire were designed in advance of commencement of survey in order to have ample time for pre-testing, under taking pilot survey and under taking training to enumerators. Attempt has been made in order to formulate questions in clarity and logical order. Especial attentions have been given towards simplifying technical terms, definitions, concepts and so on to avoid possible bias that could emanate from it.

Concerning training and supervision, DA's were selected as an enumerators for the researcher from the view point of; firstly, they are well Known to the local farmers and have acceptance from local farmers; secondly, they could have experience in data collection and thus they Know techniques of interviewing, their duties and obligation. The training was supplemented with practical demonstration and close supervision of enumerators to enhance quality of the data. In fact, data quality is also contingent on the cooperation and willingness of the farmers to provide the desired information. The objective of the study was clearly explained to the coffee producers in order to avoid possible response and non response error. To avoid inconsistency that could be raised from many enumerators; two enumerators have been employed for the data collection.

3.3 Methodology of the study

3.3.1. Model specification

A large body of theoretical and empirical literature has investigated the measurement of efficiency of farm enterprises, using various methods. Many studies have emphasized that the focus in analyzing economic efficiency should be the performance of the whole production system, including farmers and institutional support systems. These results can be used to pinpoint the factors that impede the capacity of farmers to reach their productivity potential. Technical efficiency (TE) can be estimated using one- or two-step approaches. Taking the drawbacks of two step approach in to consideration, as discussed in chapter two, one step approach is used in this study.

The stochastic production function can be specified as Cobb-Douglas, constant elasticity of substitution, Trans log, and other functional forms. Even though Cobb- Douglas has the advantage of ease of estimation and interpretation of coefficients, it assumes constant elasticity of scale and unitary elasticity of substitution and thus variation the elasticity of scale or substitution may be erroneously attributed to inefficiency. Hence functional form is a relevant consideration when estimating the production frontier Aigner et al. (1977). Moreover, evidence from Krishna and Sahota (1991) shows that if the interest rests in technical efficiency measurement not the analysis of general structure of stochastic frontier, then functional form would have a very small impact on measurement of efficiency. Given the above arguments the study used likelihood ratio test to select among the different functional form which could fit the data well. In this study we assume that the frontier technology of matured coffee production of the sample can be represented by Trans log production function and tested against restrictive Cobb-Douglas production function.

With the aim of addressing research question raised in the introductory part of this study and in light of the designed analytical framework, the appropriate empirical model specifications are made in the following two sections.

3.3.1.1. The Empirical stochastic frontier model

Following $Coelli$ (1995) and $Aigner\ et\ al.$ (1977) technical efficiency and their determinants used in this study for analytical purpose were estimated using a one step maximum likelihood estimate (MLE) procedure. Basically, the choice of functional form is of prime importance in the stochastic production frontier estimation. The more flexible functional form (Trans log specification) is generally preferred over (Cobb-Douglas specification), since it does not impose general restrictions on the parameters nor the technical relationships among inputs. Consequently, Trans log functional form is supposed to fit the data under the study adequately. This is done by incorporating the model for technical efficiency effects in the Trans log production function which is specified by relating yield as a function of farm input as follows.

$$LnY_j = \beta_0 + \sum_{i=1}^{5} \beta_i LnX_{ij} + 1/2 \sum_{i=1}^{5} \sum_{k=1}^{5} \beta_{ik} LnX_{ij} LnX_{kj} + v_j - u_j \quad \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Where *ln* designates a natural logarithm and subscripts *i* and *j*, respectively, represent the inputs *i* used by farm *j*

Y= is the observed output of the i^{th} farmer on the j^{th} farm in kg

X_1= Area under matured coffee trees (ha)

X_2= human labor used in total hours of work

X_3= amount of deprecation of agricultural equipments used in coffee production or capital (in birr)

X_4= fertilizer (quantity of fertilizer used in Kg)

X_5= age of coffee trees

β = is a (Kx1) vector of unknown parameter to be estimated

In the equation 12, the composed error term is represented by v-u. Where v_i, represents the random variable of individual i, is assumed to be identically and independently distributed as $v_i \sim iid\ (0, \delta_v^2), independent\ of\ u_i$ that measure technical efficiency relative to stochastic frontier model. Based on the assumption that u_i and v_i are independently distributed, the parameter of the above stochastic production function would be estimated using the MLE approach.

Four distributional assumptions for the distribution of u_i exists; half normal, truncated normal, exponential and gamma. As one of the objective of this study the effect of all except gamma distributional assumption of u_i, on the level of technical efficiency of each farmer, are compared empirically with the help of Stata 9 software package. Farm specific technical efficiency will be obtained, as discussed in chapter two, using the following equation (formula)

$$TE = exp\ (-u_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

3.3.1.2. Sources of Technical Inefficiency

With the help of one step approach the value of technical inefficiency component would be derived either via E(u/e) or m(u/e) given the assumptions zero mean, unknown variance δ_v^2 and non negative random term, u_i. The technical inefficiency component is assumed to be independently and identically distributed between observations, and is obtained by truncation at point zero of the normal distribution with mean μ_i (under truncated normal distribution) and variance δ_u^2. Where the mean of $u_{i,}$ μ_i is defined by the equation of the socioeconomic factor (Coelli, 1995) hypothesized as determinants of TE, can be stated as:-

$$\mu_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} + \delta_{11} Z_{11} + \delta_{12} Z_{12} + \delta_{13} Z_{13} + \delta_{14} Z_{14} + \delta_{15} Z_{15} + \delta_{16} Z_{16} + w_i \ldots \ldots \ldots \ldots (14)$$

Where; μ_i is the mean of error term under truncated normal distribution, Z's represents socioeconomic factors supposed to be the determinants of technical inefficiency component.

Z_1= Age of household head (in years)

Z_2= Level of education of farmer (years spend in school)

Z_3= Farming experience; years of active farming

Z_4= Extension visits; A dummy variable having the value of 1 if the farmer had extension visit and 0 otherwise

Z_5= off farm income; is a binary variable having the value of 1 if off farm income > 3000 birr and 0 other wise

Z_6= Credit received; A dummy variable having the value of 1 if the farmer has access to credit and 0 otherwise

Z_7= Gender of house hold head; dummy variable having a value of 1 for female and 0 otherwise

Z_8= Distance; the distance of coffee plot from home in km

Z_9= Proximity to market; the distance of plot from the nearest market in kilo meter (km)

Z_{10}=Variety of coffee planted; A dummy variable having the value of 1 if the farmer has used improved coffee trees (Java) and 0 otherwise

Z_{11}=Family pressure; Expressed as family size per total land owned by household head

Z_{12}=Slope of the land; A dummy variable having the value of 1 if the land has steep slope and 0 otherwise

Z_{13}=Soil fertility; A categorical variable having the value of 1, 2 and 3 if the soil fertility is reported to be good, medium and poor respectively.

Z_{14}=Membership in local organization; A dummy variable having the value of 1 if the household head is the member of local organization and 0 otherwise

Z_{15}= Livestock ownership; the number of livestock owned in (TLU)

Z_{16} = Amount of cereal crop production; captured by the total quantity of output produced by the farmer in kuntal

δ_i = is a (Mx1) vector of unknown parameter to be estimated

The two step approach is used for the half normal and exponential distributions to see impact of various distributional assumptions on the factors affecting technical inefficiency estimate. For this particular objective, technical inefficiency effects has been modeled using technical inefficiency variance function derived from error component model. In step one of this approach, stochastic frontier model expressed under equation (12) is estimated under the assumptions that hold with no Z variables (variables determining technical inefficiency) included and, then, technical inefficiency variance (lnsig2u) is used to obtain farmer specific estimates, $\hat{u}$. In the second step, lnsig2u obtained in step one of this approach is regressed on the vector of Z variables to obtain estimates of γ. Accordingly, technical inefficiency variance function that should be specified for the half- normal and exponential models would be modeled as:-

$$linsig2u = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} + \delta_{11} Z_{11} + \delta_{12} Z_{12} + \delta_{13} Z_{13} + \delta_{14} Z_{14} + \delta_{15} Z_{15} + \delta_{16} Z_{16} + w_i \ldots\ldots\ldots (15)$$

Where; lnsig2u is technical inefficiency variance function and δ_i *is parametres* to be estimated.

3.3.2. Method of data analysis

The model represented by the equation by (12), (13) and (14), and their respective coefficients β_0, $\beta_1 \ldots \beta_7$; and $\delta_0, \delta_1 \ldots \delta_{16}$ are simultaneously estimated by *Stata 9* using one step approach. The variables, Z_1 to Z_{16}, in the equations 14 and 15 are sought to affect the level of technical inefficiency as represented in equation (13). Evidence from various literature shows that the two step approach have serious draw backs. In order to get unbiased and consistent estimates of (β, δ_u^2, δ_v^2) from equation of stochastic frontier model, we need to be sure of that elements of Z (variables determining technical inefficiency effects) are uncorrelated with the elements of X (variables in the error component model). This needs X and Z variables are true orthogonal. The Orthogonality condition has been undertaken by running (regressing) each variable in the technical inefficiency effects over explanatory variables of stochastic production frontier. If the value of R^2 from above regression is very high, it is an indication of the presence of non-Orthogonality conditions between explanatory variables of stochastic production frontier and inefficiency effects model. The stochastic frontier and inefficiency models estimation, moreover, is based on the values of variance parameters such as gamma ($\gamma = \lambda^2/1 + \lambda^2$), lamda ($\lambda = \delta_u/\delta_v$), sigma2u ($\delta_u^2$); sigma2v ($\delta_v^2$) and sigma ($\delta^2 = \delta_u^2 + \delta_v^2$) which are simultaneously estimated using stata9. If the variance parameter λ, which implies total variation in output from the frontier due to technical inefficiency, is statistically significant it clearly reveals the presence of technical inefficiency. Similarly, the value of gamma tells us percentage of total variation caused by technical inefficiency of farmers concerned under the study.

To study returns to scale in coffee production, the scale coefficient *(*α*)* has been calculated. By definition, returns to scale are measured by the sum of partial output elasticities with respect to each input. In this study, the mean value of the farm's output elasticity with respect to each input is estimated using the following formula which is derived from Trans log model:

$$\frac{\partial lnE\ (Yj)}{\partial \ln(Xk)} = \beta k \ + \ 2\beta kk\ Ln\ (Xki) \ + \sum_{j \neq k} \beta kjln(Xji) \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

Thus, the scale coefficient α is given by:

$$\alpha = \sum_{k=1}^{n} \left(\frac{\partial lnE\ (Y)}{\partial \ln(Xk}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

The magnitude of *α (return to scale)* measures the proportional change in output resulting from a unit proportional increase in all inputs. The industry exhibits increasing returns to scale if *α* is greater than one, constant returns to scale if *α* equals one, and decreasing returns to scale if *α* is less than one. In order to verify the hypotheses of this study and to choose between the Cobb–Douglas and Trans log functional forms the one that best represents the data, we carry out the generalized likelihood-ratio test (LR). The LR test statistic (λ) is calculated as follows:

$$\lambda = -2ln[l(Ho)/l(H1)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (18)$$

where *L(H0)* and *L(H1)* are, respectively, the values of the likelihood functions derived with and without constraints imposed by the null hypothesis (H_0), H_1 being the alternative hypothesis. If the null hypothesis is accepted, Λ has a Chi-square (or mixed Chi-square) distribution with a number of degrees of freedom equal to the difference between the number of estimated parameters under H_1 and H_0.

3.4. Definitions and Measurement (Indicator) of variables used in stochastic and technical inefficiency effects models

Output: Since farmers considered under survey practice mono cropping system, physical quantity of coffee output is taken instead of the value of output harvested from the farm. This is because the value of output may be subjected to fluctuation across farmers due to variation in coffee price. When the farmer sells products on the market, transport and other marketing costs are subtracted from the market price to find the farm-gate price. Thus in this study the quantity of coffee output produced in kilogram is used for the analysis.

Land: It is measured by the area under matured coffee trees in hectare. During survey the data on size of land was collected in terms of facasa (one forth of a hectare) which later converted to hectare. Basically, land is the main factor of production and thus positive coefficient is expected.

Labor: It is measured by the total hours applied for the maintenance of matured coffee trees. In order to arrive at the amount of family labor applied for coffee maintenance, heterogeneous potential labor supply should be converted to homogeneous man-labor equivalent. This is necessitated due to the fact that working capacity differs according to age and gender. Accordingly, the conversion factor is adopted from the Food and Agriculture Organization (FAO) method. For a woman, working hours are multiplied by 0.75 and for a child below 15 years, the coefficient is multiplied by 0.5. Finally, the total working hours is summed up to reach at total labor needed for the maintenance of matured coffee trees for the last season (2008/9).

Capital: - The value of agricultural equipment is used if its economic life is less than one year. But, for equipment whose economic life is more than one year, the depreciation charges are calculated according to the rate of straight-line depreciation recorded in the course of time. In this respect, the cost of agricultural equipment is divided by its economic life to obtain its annual use cost that is used to proxy capital. The value these agricultural equipments are expressed in terms of birr.

Fertilizer: This variable is measured by adding quantities of natural fertilizer (traditional manure) applied per household in kilogram during 2008/9 on matured coffee tree in order to maintain coffee tree. Evidence from field survey shows us that coffee producers have not applied chemical fertilizer and hence organic fertilizer has been used instead. Therefore, quantity of organic fertilizer registered corresponds to the one that was applied on the matured coffee trees in the course of the last coffee season, since the impact of this input on production is only felt one year after its application. Application of fertilizer is expected to increase the level of production and thus influence efficiency positively.

Age of coffee tree: The introduction of the coffee tree's age in the production function permits us to capture its biological cycle: The young coffee plant grows for three to four years before bearing fruit. Full production starts in the ninth year and lasts until the sixty years, when a progressive decline begins. This indicates that after reaching maturity at certain age, the productive capacity of coffee trees decline. It further reflects the farmers' investment in renovation of plantation.

The household head age: This is measured by the age of household head in years. Various literatures have shown that as age of household increases, farmers tends to adapt the environments, get more experienced and challenge the problem he/she faced in the past. The degrees of inefficiency are supposed to declines as age of household increases. Therefore negative coefficient is expected to inefficiency effect.

The level of education of household head: is determined by the number of years spent in school which proxy the level of education of farmer. Educated farmers are expected to acquire, analyze and evaluate information on different inputs, outputs and market opportunities much faster than illiterate farmers. In this study education level of household head is taken in to account, on the assumption that the most farm management decisions for which education is decisive are made by the household head. The coefficient of this variable is expected to have positive impact on the technical efficiency of coffee producers.

The household head experience: the effect of this variable is captured by the level of years the household head spend in coffee active farming, which may accumulate over time due to learning by doing. The more experienced the farmer is the more efficient he/she might be. Thus, positive coefficient is expected.

Family pressure is measured by the ratio of family size to farm size. Family size is determined by the number of people living in the household including the household head during the 2008/9 coffee season and farm size is the total hectares of land owned by the farmer during 2008/9 coffee season. This variable is expected to have negative coefficient as the high pressure is expected to increase dependency ratio and could increase inefficiency. On the other hand, however, it might also have positive sign since high population could help the farmer in better maintenance of matured coffee trees.

Agricultural extension workers' contact: this refers to the number of visits paid to household coffee plot during the 2008/9 crop season. Workers extension visit helps the farmer to get information on the maintenance of matured coffee trees and how to improve its productivity therein. If the farmers have many/ continuous contact with agricultural extension workers, farmers efficiency will be expected to increase. Thus the sign of this variable is expected to be positive.

Gender of household head: is a binary variable that is included to estimate the impact of gender on technical efficiency level of farmers. Household in the study area become female headed for two reasons. The first one is if the husband is not alive and the other reason is if the husband has migrated. In case of migration, we expect remittances to facilitate the production possibilities as the house hold head can now employ more labor due to availability of cash from remittances. Female headed household would have better opportunity to carry out frequent follow up and supervisions of the farm activity on their plot. In opposite, male headed household head might be efficient as he can challenge the problem free of cultural interference.

Distance is the average time the farmer must travel from the residence to the plots. This is measured in kilometer. We expect that the more distant the plot is from the residence, the less productive the farm operation is. Thus, negative coefficient is expected. For analytical purpose, the distance variable was collected in hours it took the adult farmer on foot. Moreover, the conversion factor coated from the work of $Pavermon$ (2006) is taken as standard conversion of on foot waking hours of adult to kilometer[3].

Proximity to the market: This variable is proxied by the average distance between the most nearest market center and coffee plot. It is hypothesized that farmers who are near to market center are more technically efficient than farmers far away from the nearest market center and vice versa. This variable is measured by the distance between the most nearest market and coffee farm plot in kilometer[4].

Access to credit: The effect of this variable would be examined by binary variable; 1 if household had access to credit during last coffee season, and 0 otherwise. As availability of loans reduces capital constraints and facilitates the timely application of inputs, it is expected to positively influence technical efficiency. Hence the sign of the coefficient of this variable in the efficiency model is expected to be positive.

Off farm income: it is binary variable having value of 1 if household got off farm income above 3000 birr, and 0, otherwise. The effect on the production of farmer being involved in off farm activities may be of two fold. First, if farmer spends more time on off farm activities relative to farm activities, this may negatively affect agricultural activities. Second, income generated from off farm activities may be used to acquire purchased inputs and hence positively complement farm activities.

[3] *The average walking speed for an adult traveling at a normal pace is roughly 5 km/h. This would thus translate into one-fifth of an hour, or 12 minutes; for distance Pavermon (2006)*

[4] *The average walking speed for an adult traveling at a normal pace is roughly 5 km/h. This would thus translate into one-fifth of an hour, or 12 minutes; for proximity to market Pavermon (2006)*

Variety of coffee planted: Is also captured by binary variable having value of 1 if farmer used high yielding variety which could resist bad environmental conditions (natural or manmade) called Java variety, and 0, otherwise. The high yielding variety not only productive but also can resist difficulties. Thus, farmers with Java variety are more productive and efficient than others.

Livestock ownership: This variable stands for the number of livestock owned by the household in tropical livestock unit (TLU)[5]. It is assumed to reflect the wealth of household, and could help the farmer in diversifying the level of risk associated with coffee farming. The money from this helps the farmer to secure his/her livelihood and enable them to purchase more inputs which helps them to maintain matured coffee production. As a result it is expected to have positive impact on efficiency, as a farmer with more livestock will be able to purchase inputs and help the farmer to conduct the agricultural activity in better manner and hence improves his/her efficiency.

Cereal crop production: This variable captures the Kg of crop production excluding coffee production during the last coffee season. It could help the farmer in diversifying the level of risk associated with coffee farming. The more the farmer produces this crop the less risk associated to the coffee farming. It might be considered as the source of saving as money from coffee sale is not used for purchase of crop used for the consumption purpose. Similarly, the money from this helps the farmer to secure his/her livelihood and enable them to purchase more inputs which helps them to maintain matured coffee production. As a result it is expected to positively affect technical efficiency.

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[5]*The following conversion factors were used to aggregate the different types of livestock available to household in to common standard unit (TLU): calf =0.25; Heifer=0.75; Young bulls=0.34; sheep and goats=0.13; cow and ox=1; chicken=0.013; Donkey=0.70; hoarse and mule=1.10 (FAO, 1998; Storck, et al, 1991cited in Getu, 2005)*

Soil fertility: Plot of land differs in fertility and this, consequently, has an effect on production. A farmer may produce below the frontier due to low level of fertility of land. Thus, here the variable is expected to positively influence technical inefficiency. But negative coefficient of this variable is expected in case of good soil fertility. Soil fertility [6]measure is constructed as an index based on respondents perceptions of the quality of their plot with respect to the extent to which the plot is fertile, medium fertile and infertile.

Slope of the land: Slope of the land may affect level of production. For instance steep plots are usually subject to water erosion. As a result, they are likely to be of lower productivity. To take the effect of efficiency of different topography of the plot, an index is constructed based on the respondents' judgments. The indices for the slope of the land[7] is constructed based on the respondents response on whether the slope of their plot is flat (medda), semi-flat (dagetama) and steep (geddelamma)

Membership in local organization: This variable is captured by binary variable having the value of 1 if the household head is participating in one of local organization found around him/her. If the household head is a member of local organization, he/she can get labor assistance in case where the farmer is in difficulty and financial assistance as well. The degree of social life increases as long as the farmer is the member of that organization. This could help the farmer in improving the level of productivity and technical efficiency too. Thus positive coefficient is expected.

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[6] *land quality or soil fertility and topography of the coffee plot are encoded in the data set as best quality (fertile) and flat=1, medium fertile and semi flat=2 and infertile and steep=3*

[7] *The measure for the slope of the land is indexed as 1=flat; 2=semi-flat and 3=steep based on the response of the respondents (coffee producers)*

Chapter Four: Results and Discussion

This chapter discusses the results of the estimation of the Stochastic Frontier Approach (SFA) specified in chapter three. Both error component model and technical inefficiency effects model were developed using the one step approach. The estimate of technical efficiency and the value of technical inefficiency component were also predicted, without violating different distributional assumptions attached to u_i, using the maximum Likelihood method in Stata 9.0. In this chapter Trans log production function and Cob-Douglas production function were established and the model which describes the data set adequately was selected among the two model specification using hypothesis testing. Three different distributional assumptions, half-normal, truncated normal and exponential were made on distribution of error term, u_i. The effect these distributional assumptions on technical efficiency levels of each farmer was investigated and compared. Nonetheless, analysis was made using truncated normal distribution of stochastic frontier model.

The chapter presents results after the data have been transformed. In order to see the impacts of various distributions on the estimates of technical efficiency, the model comparison in reference to half normal, truncated normal and exponential assumptions attached to u_i have been performed. Moreover, individual farmer technical efficiency and elasticities are also estimated.

The stochastic and inefficiency models estimated before the data are transformed show that most variables in error component model and technical inefficiency effects model are statistically insignificant (see Appendix 1). However, lamda λ (the variance parameter showing the ratio between the normal error term and half normal positive error term) is statistically significant. This verifies the fact that there are measurable inefficiencies in coffee production probably caused by differences in socio-economic characteristic of the households and their management practices. The value of gamma, furthermore, signifies us that around 89% of variation in the model are caused by technical inefficiency. The result from this original model also illuminate that the mean technical efficiency of farmers in Jimma zone is around 64%. In fact, in comparison to corrected model these figures are small.

4.1. Descriptive analysis

4.1.1 Summary statistics of the variables

Table 2 shows summary statistics and mean difference across technically efficient and inefficient coffee producers gathered from sample of 149 coffee producers living in Jimma zone.

Table 2 Summary statistics and mean difference across technically efficient and inefficient households

Variable	Overall		Inefficient		Efficient	
	mean	Stdev	mean	Stdev	mean	Stdev
Output*	794.63	34.19	670.55	36.026	883	32.57
Land*	0.55	0.6312	0.6635	0.7228	0.470	0.54
Labor*	2664.9	4097.3	3900.60	4710.86	1784	3356.4
Capital*	446.04	910.135	744.33	1307.05	233.4	322.33
Fertilizer*	199.37	510.397	180.91	475.47	212.41	536.2
Age of coffee trees*	35	14.5372	25.87	13.13	40.58	12.25
Age of household head	48.17	11.24	44.43	10.21	50.8	11.23
Sex	0.9261	0.26	0.959	0.2163	0.908	0.290
Education	2.69	3.78	4.41	4.038	1.45	2.99
Experience	20.18	8.179	19.12	8.952	20.94	7.54
Extension visit	0.71	0.45	1.83	2.23	1.04	0.86
off farm income	3052	5434	3689	5636	3311	5272
Credit	308	689	451	775	206	601
Proximity to market	4.509	4.02	3.65	2.130	5.11	1.73
Distance	4.59	2.03	3.043	4.415	5.69	3.32
Variety of coffee plant	0.12	0.33	0.25	0.441	0.03	0.18
Family pressure	4.64	2.436	4.93	2.4701	4.42	2.40

slope of the land	0.34	0.478	0.54	0.501	0.20	0.40
Livestock	3.01	3.562	3.99	4.204	2.308	2.84
Cereal crop	19.02	40.19	30.17	43.84	35.54	11.08
Membership in local	0.89	0.31	0.93	0.247	0.862	0.34

Source: Study result

Stands for the variables that are statistically significant under kurtosis and skewness at one percent level of significance.

The table 2 shows us that the average coffee output is 794.63kg (approximately around 7. 96 kuntal) per hectare picked from matured coffee trees (i.e. 35 years on average) during the last coffee production season. The output, moreover, has large standard deviation. This may reflect income inequality among farmers. The average coffee plot per farmer is 0.5 hectare (compared to the national average of 1.01 hectare of land). The mean labor hours applied for the maintenance of matured coffee trees, on average, during the last coffee season was 2664.956 hours. This indicates us that the maintenance of matured coffee trees are quite labor consuming; indeed, the productivity of coffee trees are largely influenced by the level of labor being devoted for the maintenance of matured coffee trees.

One of the key assumptions to be satisfied in order to proven the reliability of the stastical tests like t-test, correlation coefficient etc is normality test. The significance test for Kurtosis and Skewness of variables of stochastic production frontier shown in the table 2 reveal that all variables of stochastic frontier model are statistically significant. For that reason, all variables are not normally distributed. In order not to affect the normality of stastical tests, this confirms that the data should be transformed.

Table 2 further shows the mean variation across efficient and inefficient coffee producers. The analysis of variance illustrated that membership in local organization, slope of the land and variety of coffee planted do not significantly explaining the mean variation across technically efficient and inefficient coffee producers. Difference between groups of samples may be observed due to chance rather than actual variation in the treatment of variables. As a result, these variables may be excluded from the discussion of technical inefficiency effects model analysis provided that they remain at edge without creating real change on the welfare of farmers. However, all the remaining variables are significantly explaining the mean variation across technically efficient and inefficient groups of samples.

Analysis of variance further shows the presence of significant difference between mean score of output produced by technically efficient and inefficient coffee producers. The difference between the two groups of sample (technically efficient and inefficient) is due to difference in actual managerial practice not by chance. The mean levels of efficiency (0.72) of farmers are taken as demarcation between inefficient and efficient coffee producers once the data have been sorted in ascending order. On average, efficient producers are producing 213kg more coffee output than inefficient farmers who are producing 670.5kg.

Results from ANOVA further show significant difference over input utilization across the two groups. Except for fertilizer, more technically efficient farmers are found to use lower units of land, labor and capital compared to inefficient producers. As a result of this, the actual output difference across farmers' technical efficiency category could be due to the actual input utilization by farmers. The analysis of variance further elucidate that there is significant distinction between age of coffee trees owned by technically efficient and inefficient coffee producers. On average, a farmer who owned coffee trees of age between 30 to 40 years old tends to be more efficient than household who owned coffee trees of age 25, the average coffee trees of technically inefficient farmers. Accordingly, coffee trees could yield more output when it is at age between 30 to 40 years. This may signify the biological cycle of coffee production.

Both age and experience of household head are also causing significant variation across technical efficiency categories of coffee producers. Based on descriptive statistics shown in the table 2, those coffee producers who are more experienced are more efficient than farmers with lower age and experience. Output variation across technically efficient farmers could be as a result of difference in age and experience of coffee producers. On average, those farmers who are technically inefficient are 10 years younger than technically efficient farmers. In addition, the difference in the level of education significantly explains variation in coffee output across technical efficiency categories.

Variation of output from its respective frontier level could be further explained due to the difference of family pressure across technical efficiency of farmers. In this case, household with lower family pressure are tending to be more efficient. There are around 4 people per hectare for efficient groups while 5 people per hectare for inefficient groups. Moreover, livestock ownership, on average, was 3.01 in TLU per household; the lowest livestock is owned by inefficient category. On the other hand, there are about 350 and 300kg per household owned by efficient farmers and inefficient farmers respectively. As a result, variation of coffee output could be explained further through difference in the level of cereal crop production and livestock ownership.

4.2. Econometrics Analysis

In the analysis of the original stochastic frontier model, heteroscedasticity condition reveals the presence of double heteroscedasticity (see Appendix 2). This is found by running variance of idiosyncratic error term or variance of the normal error term (*v*) represented by lnsig2v over variables in the stochastic production frontier and inefficiency effects model. However, in order to be sure of the level of heteroscedasticity, the Breusch Pagan test is used (See appendix 2). Some of the methods used to correct for heteroscedasticity are transformation of data into natural logarithms, the generalized least squares (GLS) which is also known as the weighted least squares (WLS), and data resampling techniques such as Jackknifing and Boot strapping. Moreover, weighted least square estimation technique is used as explained in equation 4.1 (see appendix 2).

Based on the result from table 10 presented in the appendix 2, we can conclude that almost all variables in inefficiency model have low covariance with variables in stochastic production frontier model. The presence of relatively lower covariance between the inefficiency variables and stochastic production frontier model indicates the existence of independence between independent variables of stochastic frontier variables and error term, e_i. Therefore, there is no problem of non-Orthogonality between an error term and explanatory variable, x (see table 10 in appendix 2).

The models specified in chapter three under the equation (12), (13) and (14) are analyzed after the models are corrected for heteroscedasticity. In addition, normality test should be carried out before analysis is done. If residual from selected specification has shown non normality, significance tests are invalid. However, the central limit theorem assures that inferences are approximately valid in large sample. Normal probability plot of residuals shows that an error term is normally distributed after the variables have been transformed (see appendix 4). Although, Trans log production function is more flexible than cob-Douglas production function, it might be subjected to multicollinarity problem that could result in unexpected sign of Beta's coefficients. However, when the purpose of the model is for prediction, as the case of efficiency prediction, Multicollinarity will not be serious problem Madalla (1992:pp280). Thus some degree of multicollinarity can be tolerated.

4.2.1. Hypothesis testing

To verify the null hypothesis of the study, a generalized log-likelihood ratio test was applied after the model has been corrected for the problems of cross-sectional data. If we are using maximum likelihood estimation and wish to test whether certain parameter restrictions are supported by the data, one useful and very convenient test is likelihood ratio test. In a large sample we know that Λ follows the chi-square distribution. Table 3 shows nested likelihood ratio test for stochastic (error component model) and technical inefficiency effect model.

Based on table 3, the first hypothesis is concerned about the selection of appropriate functional form that adequately fit the data. In order to select frontier model that fits the data well, two functional forms cob-Douglas and Trans log specifications are considered. Accordingly, the null hypothesis of the study is cob-Douglas production function is the appropriate functional form that fits the data set (H0: $\beta_{ik} = 0$) adequately. For this study, likelihood ratio test was used to select the best specification, among the two, that describes the data well. The likelihood ratio test here is calculated based on the formula stated under the equation (18) in chapter three. This value was compared with tabulated chi-square which is given by Kodde and Palm (1986: 1246, Table 1). The null hypothesis is rejected for all the three distributional assumptions attached to u_i even at 1% level of significance. Hence, Trans log production function is used for the analytical purpose in this study.

Table 3: Likelihood ratio test

Null hypothesis	Test statistic (λ)	D.F[#]	critical value	P-Value	Decision
1. H0: $\beta_{ik} = 0$					
Half normal	187.18	15	24.384	0.0000***	Reject H0
Truncated Normal	255.99	15	24.384	0.0000***	Reject H0
Exponential	255.92	15	24.384	0.0000***	Reject H0
Inefficiency Model					
2. H0: $\mu = 0$					
Half normal	33.49	1	2.706[8]	0.000***	Reject H0
Truncated Normal	-3.547	1	2.706[8]	0.000***	Reject H0
Exponential	50.79	1	2.706[8]	0.000***	Reject H0
3. H0: $\lambda = \delta_0 = \delta_1 = \ldots \delta_{17} = 0$					
Half normal	45.40	17	26.983	0.0002**	Reject H0
Truncated Normal	49.90	17	26.983	0.000***	Reject H0
Exponential	26.43	17	26.983	0.0670*	Reject H0

[#]D.F stands for degrees of freedom which is equal to number of parameters equated to zero

, ** and * represents significance at 10%, 5% and 1% respectively*

Source: study result

Having selected Trans log production function specification for all the three distributional assumptions explaining inefficiency term (u_i), the second null hypothesis for this study state that farmers are technically efficient and no inefficiency is attached to production level and that is to mean farmers are operating on technically efficient frontier. Putting this in simple term, Jimma coffee producers are technically efficient (H0: μ =0). However, the test statistic given by chibar2[9] strongly rejects this hypothesis at 1% level of significance in favor of inefficiency effects.

[8] *If the null hypothesis H0: μ =0 is true, this implies that the explanatory variables of the technical inefficiency effects model are not identified. Consequently, the critical value of the test statistic is obtained from Kodde and Palm (1986: 1246, Table 1) at q+1 degrees of freedom (the sum of equality and non equality restriction parameter p), and at the 5% level of significance.*

[9] *chibar2: when two models being compared only with respect to the variance component in question or when we test one sided distribution, the likelihood ratio test statistic will be displayed as chibar2. It has*

The third null hypothesis for this study states that variables included under the inefficiency effect model are not significantly explaining inefficiency of the farmers in Jimma zone that is to say algebraically (H0: $\lambda = \delta_0 = \delta_1 = \ldots \delta_{17} = 0$). The null hypothesis which states that age, educational level of farmer, sex, experience in coffee farming, off farm income, access to credit, soil fertility, cereal crop production, livestock ownership, slope of the land, variety of coffee planted, distance, proximity to market, and extension visit do not significantly influence farmer's technical efficiency level is also rejected.

4.2.2 Effects of Distributional Assumptions on Technical Efficiency Estimates (Model Comparison and Selection)

The effects of distributional assumptions of the inefficiency error term on technical efficiency of farmers will be compared and one will be selected for analytical purpose based on the characteristics they are having with the data set. Actually, from the literatures there are four distributional assumptions attached to inefficiency effects error term namely, half-normal, truncated normal, exponential and gamma. However, in this study all except gamma Hilton is discussed. The table 4 presents the estimates of stochastic production frontier for the Trans log production function specification under three distributional assumptions attached to inefficiency effect error term.

The values of log likelihood function of both truncated normal and exponential models are better than that of half normal, showing the best specification. Most of the variables are statistically significant for the exponential and truncated normal distributional assumption than the half-normal assumptions of error term, u_i. All except the interaction variables land*fertilizer,

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mixed chi-square distribution with no degrees of freedom and 1 degree of freedom. The p-value displayed takes this condition in to account.

labor*capital and capital*age of coffee trees on the rest of variables the three models have similar significant variables. These three interaction variables are statistically significant for both truncated normal and exponential models, however. This could reflect the appropriateness of truncated normal and exponential distributional assumption for the data set under the study.

Table 4: Maximum Likelihood estimates of Trans log Stochastic Production function under different distributional assumptions

Variables	Parameters	Half-normal	Truncated normal	Exponential
Constant	β_0	-6.496017** (2.926385)	-4.4393 ** (2.280247)	-4.436526** (2.279192)
Ln(land)	β_1	.2972177 (.8941614)	.9109686 (.6235984)	.9114629 (.6236032)
Ln(labor)	β_2	.7659336 (.6110456)	.3065716 (.4796555)	.3059715 (.4794287)
Ln(capital)	β_3	.0878729 (.4677334)	-.1729883 (.3881412)	-.1733829 (.3879373)
Ln(fertilizer)	β_4	-.1097541 (.1772869)	-.0647146 (.1423926)	-.0646137 (.1423373)
Ln(age of coffee)	β_5	6.538035*** (1.028521)	6.293294 *** (.8229354)	6.292967*** (.8226543)
$(\text{Lnland})^2$	β_6	-.0757894 (.0594761)	-.0612436 (.0409786)	-.0612288 (.0409535)
$(\text{lnlabor})^2$	β_7	-.0687291** (.0263589)	-.0565884 ** (.023606)	-.0565807** (.0236149)
$(\text{Lncapital})^2$	β_8	-.0157568 (.0130946)	-.0083242 (.01131)	-.0083151 (.0113136)
$(\text{lnfertilzer})^2$	β_9	.0054735 (.0082615)	.0035527 (.0068252)	.0035504 (.0068272)
$(\text{lnage of coffee})^2$	β_{10}	-.7471336*** (.0839874)	-.7726404 *** (.0742566)	-.7726851*** (.0742707)
Lnland*lnlabor	β_{11}	-.1787284** (.0600501)	-.1752932 ** (.0576442)	-.1752948** (.0576658)
Lnland*lncapital	β_{12}	.1150482 (.1054185)	.0165479 (.0862078)	.0164592 (.0862196)
Lnlandfertilizer	β_{13}	.0223308 (.0281237)	.0428243 * (.0234229)	.0428492* (.0234272)
Lnland*lnage of coffee	β_{14}	.323345** (.1305921)	.2798965 ** (.1027262)	.2798845** (.1027427)
Lnlabor*lncapital	β_{15}	.0726895 (.0492825)	.0918211 * (.0475767)	.0918449* (.0475924)
Lnlabor*lnfertilizer	β_{16}	.0164887	.0150291	.0150294

		(.0181379)	(.0136295)	(.0136325)
Lnlabor*lnage of coffee	β_{17}	-.1202023 (.1026967)	-.0648268 (.0825078)	-.0647908 (.0825293)
Lncapital*lnfertilizer	β_{18}	.0105127 (.0176131)	.0079285 (.0141776)	.007919 (.0141824)
Lncapital*lnage of ceffee	β_{19}	-.0792858 (.074568)	-.0888406 * (.0532628)	-.088836* (.0532639)
Lnfertilizer*lnage of coffee	β_{20}	-.0218028 (.0213659)	-.0186245 (.0148211)	-.0186272 (.0148241)
Variance parameters				
Lamda $\left(\frac{\delta_u}{\delta_v}\right)$	λ	7.754229 (.0476061)	8.346554	4.574677 (.0412502)
Sigma2	δ^2	.2453407 (.033585)	.132814 (.0312477)	.1075784 (.0198645)
Sigma_u	δ_u	.4912506 (.0351925)	.1309353 (.0318332)	.3204253 (.0321742)
Sigma_v	δ_v	.0633526 (.0207231)	.0018795 (.0014924)	.0700433 (.0163622)
Gamma $\left(\frac{\lambda^2}{1+\lambda^2}\right)$	γ	0.983641	.9858453	0.954396
Lnsig2u		-1.421602 (.1432772)		-2.276212 (.2008219)
Lnsig2v		*-5.518079* *(.6542159)*		-5.317284 (.4672014)
Log likelihood function		-16.565944	-7.9225945	-7.9158015
Lnsigma2			4.984066 (1.678517)	
Ilgtgamma			4.2436*** (.9212478)	
Chibar2 (1)		33.49	z = -3.547	50.79
TE (mean)		72%	72%	76%

, **, * is significant at 10%, 5% and 1% respectively*

Note: - Figure in parenthesis indicates the standard error

Source: study result

However, the estimated value of variance parameters among the three assumptions varies significantly among the three models. This may possibly due to the specification of error term that should be suitable to the data set under the study which is estimated (approximated) by the term $E(u/e)$). The estimates of gamma (γ) parameter, which indicates percentage of total variation caused by technical inefficiency of farmers, is almost similar with slight difference. In the half-normal model, 98% of total variation is caused by technical inefficiency. For truncated normal distribution and exponential on the other hand, about 98% and 95% of total variation is due to inefficiency respectively. The result from table 5 further shows both truncated normal and exponential models have similar characteristics to each other for the data set under the study.

Table 5: Summary statistic of technical efficiency distribution based on different assumptions

	Distribution of inefficiency term		
	Half-Normal	Truncated normal	Exponential
Mean	.7253024	.7247132	.7610335
Median	.76725	.8255533	.825552
Standard Deviation	.1857207	.2380949	.1948844
Maximum	.9777239	.985293	.9798859
Minimum	.2347724	.190005	.2221133

Source; study result

The result from table 5 shows that the mean variation of technical efficiency across various distributional assumptions is approximately similar to each other. The descriptive statistics from half normal, truncated normal and exponential on average reveals about 27%, 28% and 24% of output is lost due to technical inefficiency of farmers respectively.

Figure 5 further shows the estimated error term, u_i estimated through $E(u/e))$. The figure is drawn after the error term predicted has been arranged in ascending order. The estimate of inefficiency term from half normal, exponential and truncated normal distributional assumptions model are predicted based up on the formula stated in the literature review section under equation (2.18), (2.20) and (2.21) respectively. Figure 5 depicts that if the data set is analyzed using truncated normal distribution of error term u_i, most of coffee producers tend to be inefficient. On the other hand, however, taking half-normal assumption of u_i for the distribution of error term causes most of the farmers considered under the study to operate closely to efficient stochastic frontier model which implies the fact that farmers are using available technology more efficiently and consequently there is no or little output lost due to inefficiency (mismanagement of farmers).

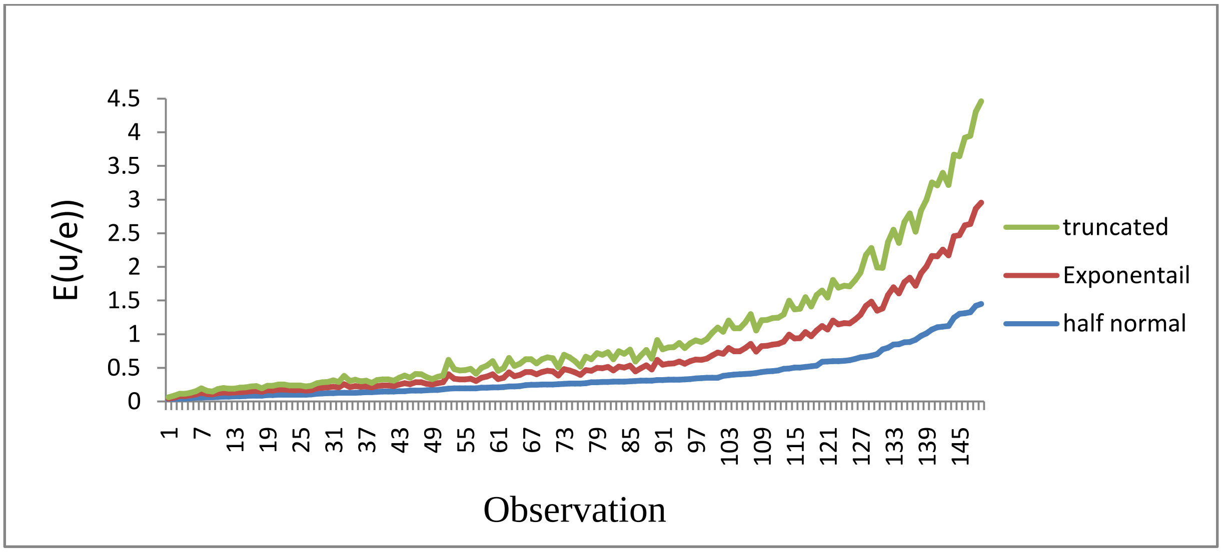


Figure 5: Estimated error term u from three models with different distributional assumptions

Source: household survey study result, 2010

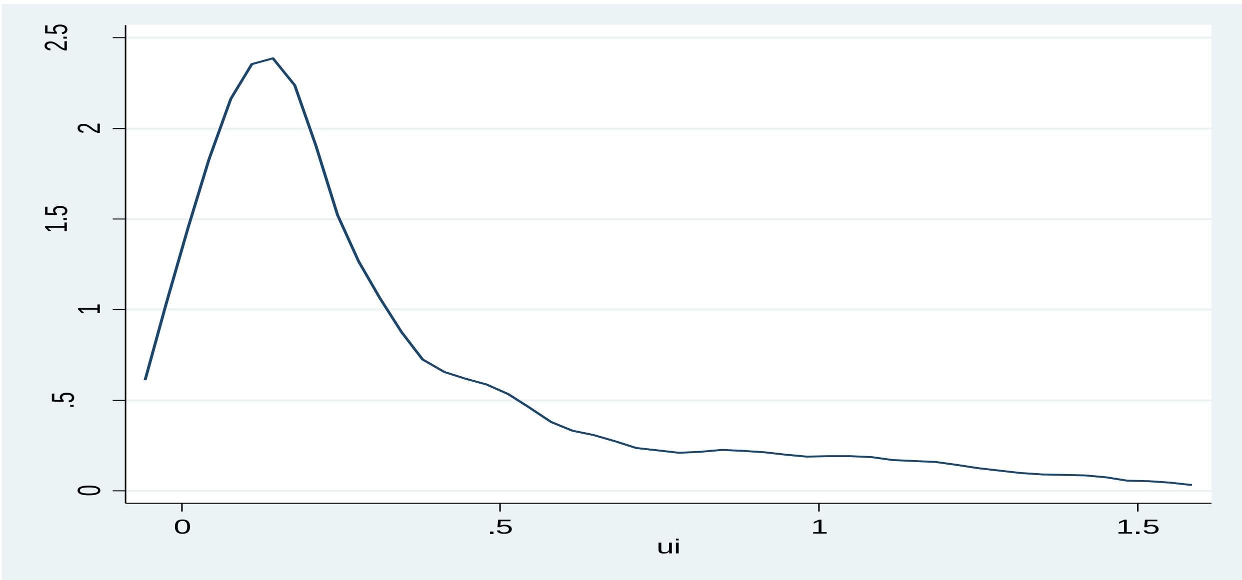
The rational issue here is selection of appropriate model. The selection shall depend up on appropriateness of distribution assumed for the data under the study. According to available data set, truncated normal and half- normal assumptions of inefficiency term could result in extreme value that is high efficiency and high inefficiency.

Though figure 5 takes us to use the moderate one (exponential), the very reason to use one step approach (Truncated normal) is to come by aforementioned drawbacks of the two step approach. In fact, exponential and truncated normal results in almost similar output in this study. Finally, what one should note here is that distributional assumptions have approximately similar impact on technical efficiency estimates apart from parameters of technical inefficiency effects and stochastic frontier models. Consequently, for analytical purpose discussed in the following sections truncated normal shall be used therein.

4.2.3. Kernel density estimation for the truncated normal distributional assumption

In order to separate error component (stochastic) and inefficiency effects in the model, a distributional assumption has to be made for u_i *Coelli* (1995). Among many empirical works on technical efficiency study, some of them like Battese and Coelli (1996); Coelli (1995); Aigner et al. (1977) show us that technical efficiency can only be estimated if inefficiency effects error term, u_i are stochastic and has a non negative truncation with truncated normal distributional specification. Accordingly, in order to confirm the assumed assumption, a kernel density function is plotted in the stata9 as follows in the Figure 6.

Figure 6 Kernel density estimation of error term, $\boldsymbol{u_i}$ under truncated normal distribution



Source: study result

The above figure 6 for the kernel density estimation of error term u_i proves (an indication of) the assumption that inefficiency effect error term, u_i is non-negatively distributed with truncated normally distribution is probably correct.

4.2.4 Technical Efficiency: Result from Truncated normal Model

The maximum likelihood estimation result of Trans log stochastic production function from truncated normal model is discussed under table 4. The estimate of lamda (8.346554) is greater than one and sigma (.364408) is large and statistically different from zero, indicating good fit and correctness of specified model for the given data set under the study. The value of gamma (.9858487) shows that about 98 percent of total variation is caused by technical inefficiency of farmers. The mean technical efficiency of farmers in Jimma zone (i.e. 0.72) indicates us that on average about 28 percent of output is lost due to coffee producers technical inefficiency that could be emanated from farmer's mismanagement practice rather than random variability. Based on the result from table 4, the coefficients of the model shall be discussed under partial elasticities and return to scale section.

4.2.5 Partial Elasticities and Return to Scale

Once Trans log production function is supposed to describe the data set under the study, the coefficients of inputs would have elasticity interpretation provided that the stochastic production function is specified in logalizm form. Moreover, the coefficient of Trans log stochastic production frontier is not directly interpretable due to presences of second order coefficients (cross products) of variables of Trans log stochastic frontier production function. Given this fact, therefore, partial elasticity of output with respect to inputs is estimated as they permit the evaluation of the effect of changes in the amount of input on the output.

Based on equation (16) stated in the chapter three, the output elasticities with respect to the inputs X_i is derived from equation 4.3 (see appendix 5) as follows:

$$\frac{\partial output}{\partial land} * \frac{1}{output} = \frac{\beta_1}{land} + \frac{2\beta_6}{land} + \frac{\beta_{11}}{land} + \frac{\beta_{12}}{land} + \frac{\beta_{13}}{land} + \frac{\beta_{14}}{land}$$

This expression can be re expressed as

$$\frac{\partial output}{\partial land} = (\beta_1 + 2\beta_6 + \beta_{11} + \beta_{12} + \beta_{13} + \beta_{14}) * {}^{output}/_{land}$$

Following this expression, elasticity of output with respect to its input can be written as

$e_{land} = \beta_1 + 2\beta_6 + \beta_{11} + \beta_{12} + \beta_{13} + \beta_{14}$

Following the specifications under equation (16) and (17) discussed in the chapter three, partial elasticity and return to scale are given in the table 6 as.

Table 6: Partial elasticity and return to the scale

Input variable	Partial elasticity
Land	0.95
Labor	0.06
Capital	0.16
Fertilizer	.0183
Return to scale	1.1883

Source: Study result

Here partial elasticity indicates the relative importance of every factor in coffee production. From the table 6 we can see that land is the main important factor of production followed by capital and labor inputs in coffee production. Accordingly, one percent increase in land input will cause coffee output to increase by 0.95 percent. In addition one percent increase in labor input increase output by 0.06 percent. Contrary to many studies, output has lower responsiveness to labor, showing labor is less productive factor of production in the maintenance of coffee farming in the zone. This may be due to either labor is not intensively utilized by farmers or labor is not allocativily efficient.

Furthermore, one percent increase in capital input increase coffee output by 0.16 percent, implying that capital plays significant role in the maintenance of matured coffee trees. Fertilizer is very crucial in maintenance of matured coffee trees and productivity of coffee output as indicated by Nichare (2007) but; in this study, fertilizer is not very important in the maintenance of matured coffee tree in the Jimma zone. This may be due to; one, farmers in the Jimma zone does not apply chemical fertilizer (in organic fertilizer) in the matured coffee tree maintenance. The application of chemical fertilizer might have been important for augmenting productivity of coffee, however. Two, applied manure in the maintenance of matured coffee trees may not be allocativily efficient to improve production and productivity of coffee output; thee, the low level of fertilizer input application might be from a few number of livestock ownership. All variables have inelastic response, indeed.

Based on the result shown, farmers could benefit from economies of scale associated with increasing returns to scale in the coffee production in order to increase the level of production. Correspondingly, one percent increase in all factors of production could cause output to increase more than one percent. Moreover, both age of coffee tree and age of coffee tree square are significant even at one percent level of significance. This confirms coffee tree’s biological cycle. During young period, after bearing fruit, coffee is more productive enough and its productivity gradually decreases as the age of coffee tree increases over time. This may also signify the importance of farmers’ investment in renovation of plantation.

4.2.6 Technical efficiency of Jimma zone by woreda

The predicted efficiency levels for five woredas in Jimma zone are shown in the table 7. The mean technical efficiency, 0.72 is taken as separation between efficient and inefficient coffee producers after the data are being sorted in the ascending order. Given the data set under the study, the efficiency level ranges from 0.19 (in manna woreda) to 0.98 (in Gomma woreda). The majority of farmers in Jimma zone have efficiency level ranging from 0.19 to 0.75, implying that there is still a room for productivity improvement, at least for the short run, through farmers' technical efficiency improvements. Before launching new technology, priority may be given for farmers' technical efficiency improvements as it further facilitates the technological innovations towards coffee production in the long run.

From table 7 one can see that technical efficiency is highest in Limmu Saqa and lowest in the manna woredas. About 88 percent of the farmers operating in Limmu Saqa woreda are technically efficient than other woredas in the sample. On the other hand, farmers operating in the manna and Gera woredas are technically inefficient (about 84 percent of farmers in these woredas are technically inefficient); reflecting significant output loss due to farmer's technical inefficacy. Other than farmers in the Manna and Gera woredas, most of farmers operating in the Limmu Saqa, Gomma, and Limmu Kosa have stable (less fluctuating) level of technical efficiency levels; implying that farmers are performing approximately similar practice for the maintenance of matured coffee trees.

Basically, the deviation of output from its frontier level could also be due to location difference in which farmers are operating their agricultural operation. The reasons for the efficiency variation across these areas might also be due to lack of resources and poor soil fertility. Using one way

ANOVA the null hypothesis that location difference has no effect on the coffee producers' performance is rejected at 1% significant level (see Table 7). Therefore, location difference has an effect on the performance of coffee producers in the Jimma zone. The location difference among coffee producers appears, in fact, due to variation of soil fertility, temperature, climate, etc. So, woreda dummy is needed to take in to account the effect of location difference on performance of farmers. However, because of existence of soil fertility index which was supposed to proxy location variation, woreda dummy is excluded from analysis. The difference in land productivity (captured by soil fertility) reveals that soil fertility differences can also be the cause for productivity variation across woredas. Further research would be needed to segregate which impact is more significant for the productivity variation at the woreda level, however.

Table 7 ANOVA test for efficiency score variation across five woredas of Jimma zone (Location difference)

Woreda name	Mean technical efficiency	Standard deviation	Max	Min	F(4, 144)	sig
Manna	47.29186	22.4509	0.961323	0.190005		
Gera	45.42506	17.3599	0.671102	0.192283		
Gomma	82.09084	13.7126	0.982452	0.493965	49.383	0.000
L/kosa	87.46172	10.3513	0.985293	0.592651		
L/saqa	88.32508	7.1334	0.952687	0.746096		
Total	72.1123	14.20162	0.985293	0.190005		

Source: Study result

The value in bracket shows calculated F value for the numerator and denominator degrees of freedom

4.2.7. Input Utilization, Technical efficiency, Actual and Potential Yield of coffee producers in the Jimma zone

The stochastic production frontier approach is also used to estimate capacity utilization. Full efficiency capacity output (potential yield) can be estimated by scaling up actual output by the efficiency score generated from this estimation process (i.e. by dividing current output or actual output by the efficiency score). According to Kibara (2005) potential yield would be estimated through the following formula

$$Potential\ yield\ = \frac{100}{Technical\ efficiency} * Actual\ output \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots\ldots \quad 4.4$$

Based on this formula the estimated potential yield predicts that there is large gap between actual and potential yield especially for those who have lowest technical efficiency score. Accordingly, the most inefficient coffee producers (0- 19) are producing actual output of 83kg per hectare although the potential yield goes up to 433kg per hectare on average. On the other hand, the most efficient farmers (90- 100) are producing actual output of 994.6kg per hectare even if the potential yield goes up to 1045.7kg per hectare. These mean that they can produce more if they could exploit their potential.

One important finding based on table 8 is that, except for the fertilizer inputs, farmers with high technical efficiency are using lower factors of production (i.e. below average). In contrary, farmers applying more fertilizer for the maintenance of matured coffee trees are technically efficient. Technically inefficient farmers are using land, labor and capital above average, implying; one, the way inputs used may not be allocativily efficient and leading them to inefficiency; two, farmers with lower technical efficiency can improve their managerial inefficiency through reallocation of factors of production for further diversification like animal rearing, cereal crop production, etc.

Table 8 Input utilization and Potential Yield by Technical Efficiency Categories, on Average

Category of Technical Efficiency	Frequency (%)	TE (%)	Land (ha)	Labor (hrs/ha	Capital (depreciation cost/ha	fertilizer (kg/ha)	Actual yield in kg/ha	Potential Yield in kg/ha
0-19	2	19	0.2	1264	350.29	0	83	433
20-29	5	25	0.44	4290	432.6	2.5	153	585.5
30-39	8.7	35	0.62	4417.2	503.2	115.3	334.6	933.7
40-49	5.3	44	0.53	2139.8	367.5	50	346.8	766.6
50-59	5.3	56	0.58	3432.1	362.7	150	612.5	1084.8
60-69	10	64	1.09	5713.5	1477.9	533.3	1451.6	2268
70-79	10.7	74	0.50	1726.1	418.9	143.7	837.5	1136
80-89	18	84	0.39	1987.4	209.8	174.7	703.7	832.7
90-100	34	94	0.50	1764.3	252.5	227.9	994.6	1045.7
Over all mean	100	72	0.55	2665	446	119	794.5	1080

Source: Study result

As the level of technical efficiency increases, the gap between actual and potential output decreases. Output loss due to technical inefficiency is being minimized across technically efficient coffee producers (inputs are being used to their utmost capacity) therein. About 34 percent of farmers are technically most efficient (90-100). Evidently, farmers ranging in the category of (60-69) can produce the highest actual yield (1451.6kg per hectare) and potential yield (i.e. 2268kg per hectare on average). The input utilization of these farmers might have helped them to produce such high output and even these farmers should have to exploit their potential by further improving the way they were following over input utilization. Farmers falling in the technical efficiency category of 50s, 60s and 90s have high potential of coffee production in the zone. This clearly shows as they can produce more by improving their technical efficiency. Reconsider the table 8 for more

4.2.8 Analysis of Factors Affecting Technical Inefficiency

In the analysis of technical inefficiency effects model, the sign of coefficients of the model is taken in to account based on the analysis of (Coelli, 1996). If the coefficient of the parameter in the model is positive, it means that the variable is increasing the level of technical inefficiency of the farmer and whereas, if the sign of the coefficient of the parameter is negative, it shows that the variable under consideration is decreasing the level of technical inefficiency or increasing the level of technical efficiency of farmers.

Table 9 shows variables that explain technical inefficiency of coffee producers in the Jimma zone. Among the variables that are supposed to explain technical inefficiency, education level of farmers, off farm income, distance, family pressure, gender, proximity to market, cereal crop production, and soil fertility of the farm are significantly influencing technical inefficiency of coffee producers. The other remaining variables such as age, credit, extension visit, livestock ownership, experience, and variety of coffee planted are insignificant, however.

Off farm income is significantly explaining technical inefficiency of coffee producers in Jimma zone. It has negative coefficient; indicating that coffee producers who have more off farm income are tending to be more efficient. This is due to the fact that income generated from off farm activities may be used to acquire purchased agricultural inputs like labor, capital, fertilizer and other. By nature, productivity of coffee tree is highly influenced by the degree of maintenance being allotted for the matured coffee trees. The cost of maintenance is so high that it entails effective and efficient utilization of factors of production. Hence, the availability of off farm income positively complements farm activities. This finding is also consistent with the result of Getu (2005).

Contrary to the result reported in Nichare (2007), the variable credit becomes insignificant. This may be due to availability of off farm income, which becomes significant, as an alternative to credit. Most of the farmers considered in the sample have off farm income generated from various activities. Taking this in to consideration, in this study, farmers are categorized in to two as those farmers who are earning off farm income above and below 3000 birr per year. In peasant farming, if the farmers are earning more income, the desire for credit requisite won't be so strong. This could be due to: first, peasant farmers are risk averse; second, low income peasant farmers do not give priority to speculative motive and etc.

Table 9 Technical inefficiency effects model estimation based on truncated normal distribution

Inefficiency model	**Parameter**	**Coefficient**	**Standard error**	**t-ratio**	**p-value**
constant	δ_0	.8051226*	.4856537	1.66	0.097
Age	δ_1	-.0085573	.0092094	-0.93	0.353
Sex	δ_2	-.5244475**	.2248854	-2.33	0.020
experience	δ_3	-.0108294	.0125931	-0.86	0.390
education	δ_4	.0482628*	.025382	1.90	0.057
off farm income	δ_5	-.574535***	.1397599	-4.11	0.000
Credit	δ_6	.0345781	.1293868	0.27	0.789
proximity to market	δ_7	-.1156005**	.0467886	-2.47	0.013
Distance	δ_8	.0561252**	.0209799	2.68	0.007
slope of the land	δ_9	.0957778	.1159954	0.83	0.409
Livestock	δ_{10}	-.063555	.1743779	-0.36	0.716
Cereal crop	δ_{11}	-.75782***	.2081896	-3.64	0.000
variety of coffee planted	δ_{12}	-.0552876	.1780938	-0.31	0.756
family pressure	δ_{13}	.0689658**	.0342117	2.02	0.044
Good soil	δ_{14}	-.4472661**	.1405494	-3.18	0.001
Poor soil	δ_{15}	.437561***	.1107055	3.95	0.000
Extension visit	δ_{16}	.0179071	.1245728	0.14	0.886

Source: study Result

*, **, *** *significance at 10%, 5% and 1% respectively*

Education is expected to enhance managerial and technical skills of farmers. Evidence from many empirical findings proves that the variable has shown mixed result. According to result reported in Alemu et al. (2009) education decreases efficiency. The argument is as the level of farmer's education increases, he or she may get better opportunity outside farming sector. Ultimately, this reduces labor availability for coffee production in the household thereby lowering efficiency. Contrary to this arguments, evidence from Battesse and Coelli (1995) shows that education enhances ability to utilize available technology and increases efficiency of farmers thereby.

Education levels of farmers are significantly and positively affect the level of technical efficiency of farmers operating in Jimma zone, supporting the first argument. This may be due to the fact that farmers with better education could join non farm sector provided that most farmers want to leave farming sector if they do have an opportunity. This probably will reduce labor allocation towards coffee farm maintenance including supervision and productivity enhancing activities. Basically, lower education might be in terms of providing basic education service which is related to actual coffee farm operation in view of the fact that farmers with lower education level have less opportunity to leave farming sector.

Another factor affecting technical inefficiency of farmers producing coffee in Jimma zone is proximity to the market. It was proxied by the distance between plot and the most nearest market center in kilometer. There are several arguments attached to the sign of coefficient of this variable. On one hand, it is hypothesized that farmers nearer to market centers are more efficient than farmers away from the centre. Consequently, farmers near market center could get more hot and vital market information and may also participate in other income generating activities that could ease resource used in the maintenance of matured coffee trees and thereby enhance technical efficiency. On the other hand, farmers near market center could get an opportunity to work on non farming activities that can reduce labor allotted for maintenance of matured coffee trees. Proximity to the market negatively explaining the inefficiency of farmers, reflecting that those farmers who are close to market centers are technically more efficient than farmers away from nearest market center. These farmers may invest time through income they could get away from coffee farming given that farmers near market may participate on various income generating activities.

Distance is also another variable affecting technical inefficiency of farmers. In many empirical studies it is hypothesized that distance between plot and home increases the level of inefficiency of farmers. In line with this hypothesis, the coefficient of the variable is found to be positive and statistically significant at 10 percent level of significance. The more distant the farmer plot is from home, the more technically inefficient the farmer is. This could be due to the fact that; one, the level of close supervision may not be so strong when the plots are far away from home; two, coffee farm plot which is outlying from home could be affected by negative externalities like theft, pest and wild animals; three, disease like coffee berry could attack the coffee fruit.

Cereal crop production is another factor affecting technical inefficiency of producers. Moreover, the variable is significant at 5 percent with negative coefficient. The more the farmer produces this crop the less risk associated to the coffee farming. This would mean that farmers producing more cereal crop are technically efficient than farmers producing less of cereal crops. This could minimize risk associated with coffee crop production as income generated from this could subsidize coffee loss and livelihood of farmers. Beside this, it could also subsidize resources used for coffee maintenance. This encourages efficient utilization of resources as labor allocation between coffee and cereal crop production might reduce idle resources and also income generated may help to hire labor in case of scarcity.

The other important variable affecting technical inefficiency of coffee producers is soil fertility. The measure of soil fertility is constructed by forming indices based on farmer's perception about the productivity of soil (the quality of the soil). Accordingly, farmer's perception has been organized into three groups as good fertility soil, medium fertility soil and poor fertility soil. Accordingly, fertility of soil significantly influences technical inefficiency of farmers. Farmers' operating on poor soil fertility seems to be more technically inefficient than others while those farmers operating on good soil fertility is technically efficient than others who are producing on poor and medium quality soil fertility type. Moreover, the result from one way ANOVA shows that location difference which is further proxied by soil fertility has significant effect on the performance of coffee producers. So, land productivity could be taken as cause for significant output loss.

Gender of household head is found to be negatively influence technical inefficiency. Actually, female would be a farm household head for three reasons: when her husband died (widowed), when her husband migrated, when she is unmarried. In case of migration we expect remittance that could facilitate and finance production possibilities and possible risk associated to coffee production. In the other two cases, it opens good opportunity for female headed farmers to carry out frequent follow up and supervision of their farm. This could be highly influenced by the environment in which these households live. Observation during survey also justifies the above arguments. Accordingly, it is hypothesized that female headed household head is more technically efficient than male.

The other important variable explaining technical inefficiency of farmer is family pressure. It is measured as the ratio of family size per household farm size. This variable is expected to have positive coefficient as the high pressure is expected to create dependency ratio and ineffectiveness. On the other hand, it might also have negative coefficient as high population could help the family as source of labor for coffee maintenance and harvest the coffee on time. The result of the study justifies that as family pressure increase, the level of technical inefficiency increases and vice versa. For family with large family pressure we would expect: internal clash that is supposed to decrease production and productivity of coffee producers, high dependency ratio resulting in less production and productivity. High family pressure could also bring high cost of living and hence leading to less or no family level investment, which may lead to inefficiency in face of scarce resource.

Another important factor considered in this analysis was access to extension services. The results of the analysis in Table 9 reveal that neither extension visits nor visits and trainings have brought significant impact on efficiency levels of farmers. This could be due to the fact that development agents remain at the edge, never reaching the farmer and that the training packages may not fit the agro-ecological settings (location difference). Moreover, the type of training provided may not be output oriented.

Chapter Five

5.1 Conclusions and Policy implications

5.1.1 Summary and conclusions

Coffee is very important cash crop deserving particular attention in Ethiopia. The evaluation of the comparative advantage of coffee export crops among African countries revealed low domestic resource cost (DRC) for Ethiopian coffee relative to other African countries Pearson et al. (2007), implying the country's significant comparative advantage in coffee production. Nevertheless, Ethiopian has not yet exploited its comparative advantage in coffee production and Ethiopian coffee production and its productivity level are not satisfactory that could uphold the country's comparative advantage Nicolas Petit (2007).

Evidence from various literature shows that efficiency study should be given priority down to productivity studies, even when one wants to launch new technology, that imply the possibility of developing new technology and prompt adoption of new technological innovations towards agricultural sector on the way to improve production and productivity. Moreover, empirical studies suggest that farmers in developing countries fail to exploit fully the potential of a technology making inefficient decisions. Hence, policy makers have started to recognize that one important source of growth for agricultural sector is efficiency gain through greater technical efficiency in the short run which compliments production and productivity growth through technological adoption in long run.

This study attempts to measure technical efficiency of coffee producers in Jimma zone, examine potential to increase output without additional inputs, identifying its determinants and compare the impacts of various distributional assumptions on the technical efficiency estimates. To this end, a cross sectional household survey have been conducted on sample of 150 coffee producers selected randomly from five woredas of the Jimma zone. The stochastic frontier model was estimated under Trans log model specification. In order to see the impacts of distributional assumptions of inefficiency effects on the technical efficiency estimates, the three distributional assumptions that have been considered in this study are half normal, truncated normal and exponential models. The result of this models shows that various distributional assumptions of technical inefficiency effects have low impacts on the technical efficiency and parameters estimates. Among the three distributional assumptions, truncated normal model was selected for analytical purpose.

In order to avoid biased results, the model is corrected for heteroscedasticity. In addition the Orthogonality condition (a zero covariance between independent variables and the error term) is imposed. Results show that the overall mean technical efficiency is estimated at 72 percent. The fact that the average efficiency level is relatively lower, perhaps compared to studies in other countries, suggests that there is slight room for efficiency improvement, given current technology, refuting Schultz's hypothesis at least for short run. Therefore, there is a 28 percent scope for increasing coffee production by using the present technology (or in other words, on average, about 28% of coffee output is lost yearly due to technical inefficiency of farmers). However, TE ranges between 19 to 98 percent among the coffee producers in the Jimma zone.

The analysis of partial elasticity of coffee output with respect to inputs reveals that land is very important inputs in coffee production with capital and labor following. One percent change in land, capital, labor and fertilizer inputs causes output to change by 0.95, 0.16, 0.06 and 0.0183 percent respectively. All inputs have inelastic response to output. In fact, the sum of partial elasticity of inputs is 1.1883; implying farmers can enjoy economies of scale related to coffee production. A proportional change in inputs causes output to increase by more than proportional change. All except fertilizer all other inputs are being utilized in lower quantities by farmers who have higher technical efficiency and vice versa. Basically, the gap between actual and potential output level is being minimized across technically efficient categories of farmers. Farmers with lower technical efficiency have higher potential to exploit through technical efficiency improvements.

Furthermore, the estimated value of the variance parameter gamma (γ) for the stochastic frontier production function is not only close to one, but also significantly different from zero. This results show the existence of technical inefficiencies in coffee production. In fact, this is also further verified by rejection of null hypothesis stating joint impacts of technical inefficiency effects are null. Moreover, the value of lamda (ʎ) is greater than one and sigma (δ) is large and significantly different from zero indicating good fit and correctness of specified distributional assumptions.

Analysis of technical inefficiency indicated which aspects of the farms, human and physical resources might be targeted by public investment to improve farmers' technical efficiency. Technical inefficiency effects model shows that gender is significantly influence technical efficiency. Female household is more technically efficient than male household head, demonstrating their management capacity. This underlies their important contributions in addition to household chores. This shows that females have strong commitment over coordination, supervision of coffee farming and other managerial practices if they would have an opportunity to manage.

Moreover, as the education level of farmers increase coffee producers tends to be technically inefficient, implying that basic education is more important for the farmers than higher education. This could be due to the fact that those farmers with higher education level have an opportunity to join non farm sector that have high probability to decrease labor allotted to farming sector.

Environmental factors could be another factors affecting technical efficiency of farmers. The inherent nature of land might also affect the productivity of coffee producers. Here in this study too, farmers who are operating on poor soil quality are tending to be more technically inefficient than farmers who are operating on medium and good soil fertility and vice versa. Location difference has significant impact on the performance of coffee producers. This further poses the question whether Farmers who are technically efficient might further improve their technical efficiency by better maintenance of the soil. In fact, stochastic frontier approach fails to take in to account environmental factors that also influence technical efficiency measures.

Diversification of activity, in terms of participating in off farm income generating and cereal crop production, can improve technical efficiency of coffee producers. The income from diversification might help the farmer to secure daily livelihood, saving that help the farmer for family level investment or more, to purchase necessary inputs that helps coffee maintenance, and insurance against coffee loss. This encourage efficient utilization of resources as labor division between coffee and other might reduce idle resources and also income generated from such work encourage hired Labor in case of scarcity. In this study, credit becomes insignificant. The availability of off farm income might take over the importance of credit; implying availability of off farm income might act as the role of substitution effect.

Furthermore, farmers who are far from their plot is technically inefficient than those of farmers who are near their plot. The main implication here is that government can improve farmers' technical efficiency by expanding rural road project in side rural areas. Apart from government, the society itself could play a great role in construction of their local road at least to bring short run output effect. Besides, farmers who are near market center are more technically efficient.

The result of the study justifies that as family pressure increase, the level of technical inefficiency increases and vice versa. For family with large family pressure we would expect: one, internal clash that is supposed to decrease production and productivity of coffee producers; two, leading to high dependency ratio which results in less production and productivity; three, high family pressure could bring high cost and extravagancy leading to less or no family level investment, leading to inefficiency in face of scarce resource. The estimated value of this variable is positive and significant at 5 percent.

5.1.2 Policy Implications

Based on the results of the analysis, the study has got some policy implications. In fact, conclusive policy recommendations may require a more detailed analysis, possibly a more extensive set of data set with large sample size than this study. Moreover, the use of data from a single season to measure efficiency may result in some farmers being labeled as inefficient because of low stocking rates, when a longer time they may be shown to be more efficient because of more conservative approach Coelli (1996). Accordingly, the following policy implications can be highlighted.

Firstly; on average the wide variation in the level of technical efficiency from full capacity (potential) technical efficiency discloses the fact that there is ample opportunity for coffee producers to increase coffee output at existing levels of inputs and present technology at the hand of coffee producers. Actually, some productivity gains linked to improvements in technical efficiency can still be realized in the coffee subsector in Jimma zone. Moreover, producers can still take advantage of increasing returns to scale to boost coffee productions at least for the short run. When there is no output lost due to technical inefficiency of farmers, introduction of new technology in the coffee production would be feasible. Therefore, introduction of new technology in the coffee sub sector of Jimma zone, in short run, may results in unsatisfactory outcome. Technical efficiency improvement should be given priority setting therein.

Secondly; in the effort to improve productivity and efficiency of coffee producers in the Jimma zone public investment over rural infrastructures should be advocated. The study has shown that technical efficiency of farmers could be improved if the distance between home and plot is improved. Moreover, this could be done if inter woredas of Jimma zone can be networked through improved road facility. These probably facilitate close supervision, monitoring and maintenance of matured coffee trees. Besides the road net work in the rural areas; development of telecommunication facilities, rural market centers (institutions) should have to be advocated nearby farmers. Doing so may increase technical efficiency of producers and thereby reduces output lost as a result of technical inefficiency. In fact, the variable proximity to market is advocating this second issue. Furthermore, apart from road and telecommunication net work; basic education should be targeted to household coffee producers. Here in this case policy makers must aware of level of education should be given priority in order to avert output lost due to technical inefficiency of coffee producers. In this study, it has been verified that farmers with higher education have ample opportunity to join non farming sector which probably reduces time allotted for coffee production.

Thirdly; based on the result from the variable off farm income and cereal crop production; diversification of activities should have to take place to enact technical efficiency of coffee producers. Those farmers with high off farm income are tending to be technically efficient. One important policy implication here is that government should have to create job opportunity in the rural areas. Farmers' specific technical efficiency could also be improved if the farmers participate in self employment opportunity, indeed. However, the result of the study further illuminated that those farmers who are additionally producing cereal crop are technically efficient. In fact, this could be taken as an insurance against probable risk associated with coffee production. It can insure the livelihood of the farmers besides coffee loss in the face of uncertainty. Consequently, government should advocate diversification (or and integration) in the coffee production in the Jimma zone who have habit of producing single crop, coffee.

Fourthly; the result from the study further illustrate that environmental factors can also affect technical inefficiency of the producers. Following this conclusion, what government might do includes: soil fertility maintenance program, initiation of mitigation and adaptation measures to climate change and research and development to coffee variety which could adapt the location variation across woredas. Moreover, coffee producers can further promote their output by applying organic fertilization on the matured coffee trees.

Fifthly; females should be given an opportunity in the management position in the coffee farming sector too. The result of the study shows those female headed households are technically more efficient than male headed household, demonstrating females' management capacity. This underlies that females' play great role in agricultural production apart from their burden in household chores. Actually females' leadership (and or headship) might come from educating females, creation of job opportunity for females and public awareness on the females' ability to manage and etc.

Sixthly; the study has shown that those coffee producers with high family pressure are technically inefficient. What government should do here that; one, economic empowerment through creation of job opportunity by creating possible investment opportunity there; two, family planning programme intended to create proportional change between economy of household and its family size.

As it has already been observed, there is a potential to increase production through improving technical efficiency of coffee producers. This does not mean however, that increasing package of new technology and improving traditional practices and instruments should be neglected. Output augmenting though improvement of technical efficiency of farmers at existing technology is of short run solution. Moreover, introducing of new technology for augmenting production is of long run solution. Thus, policy makers should pursue the way to utilize both effectively but priority may be given to technical efficiency improvements.

Finally, the results obtained in this study should be considered in relative sense magnitudes. Moreover, the model used, which is cross sectional in nature, is limited in the sense that it does not consider other factors such as risks, market imperfections. Theoretically, all except gamma distribution is discussed. Moreover, it may be interesting to look at technical and allocative efficiency using panel data collected from coffee producers to see and evaluate how technical efficiency has changed over time.

Referances

Aigner, Lovel and Schemidt .1977. “Formulationa and estimation of stochastic frontier production function models”. *Journal of Econometrics,*1: 21-37.

Alemu, Nuppenua and Bolland .2009. “Techinica efficiency of farming systems across agro ecological zones in Ethiopia: an application of stochastic frontier approach”. *Agricultural Journal,* 4: 202-207.

Battese and Coelli .1995. “Model for Techinical inefficiency effects in Stochastic Frontier production function for Indian Paddy producers using panel data”. *Emperical Economics,* 20:325-332.

Bruderl. 2004. *Applied Regression using STATA.* 3rd edn. New York. Mackmillan international idition.

Cardena . 2005. “Analysis of production efficiency of Mexican coffee producing districts.” AAEA Working Paper No. *134280.*

Coelli .1995. “Recent developments in frontier modelling and efficiency measurments”. *Australian Journal of Agricultural Economics,*3: 219-245.

Coelli .1996. “A guide to FRONTIER 4.1: A computer program for stochastic frontier producion function and cost function estimation”. CEPA Working Paper 96/97. Australia, Memeo.

Coelli and Battese .1996. “Identification of factors which influence the techinical inefficency of Indian farmers”. *Austrialian Journal of Economics,* 40:103-28.

Coelli and Battese .1998. *An Introduction to Efficiency and Productivity Analysis.* Boston: Kluwe Acadamic Press.

Deprins, Simar and Tulkens .1984. “Measuring labor efficiency in post offices”. In Marchand, eds., *The Performance of Public Enterprises: Concepts and Measurements*, pp. 243–67. Amsterdam: North-Holland pp. 243-67.

EASS .1990-2008. *Ethiopian Agricultural Sample Survey by Ethiopian Centeral Statistical Authority*. Addis Ababa.

FAO .1998. "Tropical livestock unit: Food and Agricultural Organization ". At *www.fao.org*., Retrieved February 2010.

FAO .2003. *Measuring and Assesing capacity in Fisheries: Appendix C: Stochastic Production Frontier analysis*. FAO Fisheries Techinical Paper 433/2. Food and Agriculture Organization, Rome.

Farrell .1957. “Measurment of productive efficeincy”. *Journal of Royal Statical Society, series A* ,120(3): 253-90.

Getu .2005. “Technical efficiency of small holder cereal production in Ethiopia: a stochastic frontier analysis using panel data from selected villages”. Msc thesis. Economics Department: Addis Ababa University.

Greene .1980. "Maximum likelihood estimation of Econometric frontier function". *Journal of Econometrics* , 27-56.

Greene. 2000. “Simulated Likelihood Estimation of the Normal Gamma Stochastic Frontier Function”. *Journal of Econometica*, New York.

Gujarati .1995. *Basic Econometrics.* 3rd edition. New York: McGraw Hill companies.

Helfand .2003. "Farm size and determinants of productive efficiency in the Brazilian center west". Paper Presented at 25th International Conferance of International Association of Agricultural Economists (IAAE), Durban, South Africa.

Huang and Liu .1994. “Estimation of a non neutral stochastic frontier production function”. *Journal of productivity analysis,* 4: 171-80.

Jema .2008. “Economic efficiency. and marketing performance of vegetable production in the eastern and centeral parts of ethiopia”. Doctorial thesis. Faculty of Natural Resource and Agricultral Economics, Appsala, Swidish University.

Jondow, Lovell and Schimidt .1982. “On estimation of techinical inefficiency in stochastic frontier production function model”. *Journal of Econometrics,*19: 233-38.

Kibara .2005. “Techinical efficeincy of Kenya's maize production: An application of stochastic frontier approach”. Msc thesis. Colorado State University.

Kodde and Palm .1986. “Wald criteria for jointily testing equality and inequality restrictions”. *Journal of Econometric Sociaty,* 54: 1246, Table 1.

Krishna and Sahota. 1991. “Technical efficiency in Bangladish manufaturing industries”. *Journal of Bangladish Development Studies,* 4:430.

Kumbihaker, Ghosh and McKuckin .1991. “A Generalized production frontier approach for estimating determinants of inefficiency in U.S. dairy farms”. *Journal of Business and Economic Statistics* (9), 279-86.

Maddala. 1992. *Introduction to Econometrics.* 2nd, Edn., New York: Cambrige University

MARD .2008. “Agricultural gowth in ethiopia”. *Ministry of Agriculture and Rural Development year bulletin. Addis Ababa*.

Meeusen and Van Dan Broeck .1977. "Efficiency estimation from Cobb- Douglas production function with Composed Error". Journal of *International Economic Review , 18*: 435-444.

Nega Wubeneh .2006. "Techinical efficiency of Smallholder Dairy farmers in Centeral Ethiopian Highlands". International association of Agricultural Economists Conference, Purdue University.

Nicholas .2007. "Ethiopian Coffee sector: A bitter or A better future". *Journal of Agrarian Change , 7*:225-265.

Nyemeck .2003. "Factors affecting techinical efficiency among Coffee farmers in Cote d'Ivoire:Evidence from center west region". Final Report, AERC, Nairobi.

Nchare, A. 2007. *Factor affecting techinical efficiency of Coffee producers in Cameroon*. *AERC research paper 163.* African Economic Research Construim, Nairobi.

Pavermon. 2006, June 29. *http:// ansewers.yahoo.com*. Retrieved February 30, 2010, from yahoo.com.

Pearson and Ronald. 1974. "Comparative advantage among african Coffee producers". *Journal of Agriculture and Applied Economics Association* , 310-313.

Pindick and Rubinfeld. 1998. *Econometric Models and Economic Forcasts.* California: McGraw Hill International Idition.

Reifschneider and Stevenson .1991. "Systematic depatures from the frontier: A frame work for the analysis of firm inefficiency". *International Economic Review* ,32: 715-23.

Schultz, T. W. 1964. *Transforming Traditional Agriculture*. New Haven: Yale University Press.

Seyoum, Battese and Flemming. 1998. "Techinica efficiency and productivity of maize producers in eastern Ethiopia: a Study of farmers within and outside sasakawa global 2000 project". *Journal of Agricultural Economics*, 19:341-348.

Snedecor and Cochrane. 1980. *Statistical method*. 7^{th} edn., IOWA state university Press.

Tassew, Gebreegziabher and Oskam .2004. "Technica efficiency of peasant farmers in northern Ethiopia: A stochastic frontier approach" .Addis Ababa.

Tewodros .2001. "Farm household techinica efficeincy: A stochastic frontier analysis: a study of rice producers in Mardi water land in western development region of Nepal". Msc thesis. Department of Economics and Social science, Norway.

Torgerson and Palmer .1999. *Introduction to Health Economics.* New York.

Tsegaye Yilma . 2004. Techinical efficency of maize production in southeastern Ethiopia: A case of Jimma Zone.

Weir and Knight . 2000. "Educational Externalities in Rural Ethiopia: Evidence from average and production Function". *Working paper CSAEWPS 2000-4,* University of Oxford.

List of Appendices

Appendix 1: The result of original stochastic and inefficiency model

Variable	Parameter	Coefficient	Standard error	Z-ratio	P- value
Stochastic frontier model					
Lnoutput					
Constant	β_0	-6.90193	3.779169	**-1.83**	0.068
Lnland	β_1	0.297205	0.89417	0.33	0.74
Lnlabor	β_2	0.7659595	0.611051	1.25	0.21
Lncapital	β_3	0.087904	0.467733	0.19	0.851
Lnfertilizer	β_4	-0.10975	0.177289	-0.62	0.536
lnage of coffee	β_5	6.538109	1.02853	**6.36**	0.000
Lnlnadsqr	β_6	-.1014729	.0412047	**-2.46**	0.014
Lnlaborsqr	β_7	-.0063093	.0236806	-0.27	0.790
Lncapitalsqr	β_8	.023319	.0184595	1.26	0.206
Lnfertilzersqr	β_9	-.0018719	.0073961	-0.25	0.800
lnage of coffeesqr	β_{10}	-.6975859	.1034666	**-6.74**	0.000
Lnlandlabor	β_{11}	-.0376901	.0702898	-0.54	0.592
Lnlandcapital	β_{12}	-.0351294	.0901383	-0.39	0.697
Lnlandfertilizer	β_{13}	.0365716	.0192564	**1.90**	0.058
lnlandage of coffee	β_{14}	.1355556	.152812	0.89	0.375
Lnlaborcapital	β_{15}	-.0510413	.0607504	-0.84	0.401
Lnlaborfertilizer	β_{16}	.004434	.01394	0.32	0.750
lnlaborage of coffee	β_{17}	-.1240149	.0924838	-1.34	0.180
Lncapitalfertilizer	β_{18}	.0231877	.0138805	**1.67**	0.095
lncapitalage of ceffee	β_{19}	-.0131235	.1130781	-0.12	0.908
lnfertilizerage of coffee	β_{20}	-.0098556	.0137044	-0.72	0.472
Inefficiency model					
Constant	δ_0	-.6011201	1.196726	-0.50	0.615
Age	δ_1	-.02787	.0196821	-1.42	0.157
Sex	δ_2	-.2958395	.6246268	-0.47	0.636
Experience	δ_3	.0357618	.0257238	1.39	0.164
Education	δ_4	.0825882	.0497176	**1.66**	0.097
off farm income	δ_5	-1.396268	.3410709	**-4.09**	0.000
Credit	δ_6	.0730891	.4075466	0.18	0.858
Distance	δ_7	-.3170325	.0951288	**-3.33**	0.001
proximity to market	δ_8	.0306807	.0309202	0.99	0.321
membership in local org	δ_9	.4365721	.4764644	0.92	0.360
slope of the land	δ_{10}	.6618969	.323342	**2.05**	0.041

Livestock	δ_{11}	.0187671	.074147	0.25	0.800
cereal crop	δ_{12}	.0200013	.0084174	**2.38**	0.017
variety of coffee planted	δ_{13}	.1727451	.603456	0.29	0.775
family pressure	δ_{14}	.1238187	.0752975	**1.64**	0.100
variance parameter					
Lamda	ʎ	2.784691	.0684677	**113.25**	
Sigma	δ	.5074693	.0694681	**2.7027**	
δ_u^2		.7065184	.050614		
δ_v^2		.0911107	.0298044		
Gamma	γ	0.885773			
Lnsig2u		*-.6948122*	*.1432771*	***-4.85***	*0.000*
Lnsig2v		*-4.791361*	*.6542468*	***-7.32***	*0.000*
Log likelihood function		*-26.58658*			
Chibar2 (1)		*33.49*			*0.000*
TE		**64%**			

Source: result from field survey

Appendix 2 Heteroscedasticity test

Variable	Parameter	Coefficient	Standard error	Z-ratio	P- value
lnsig2u (Variance of inefficiency/hfu)					
Lnoutput					
Constant	β_0	-103.7871	29.83163	**-3.48****	0.001
Lnland	β_1	.1900857	5.69065	0.03	0.973
Lnlabor	β_2	5.869324	4.517644	1.30	0.194
Lncapital	β_3	12.80874	3.090947	**4.14*****	0.000
Lnfertilizer	β_4	2.436951	1.271201	**1.92***	0.055
lnage of coffee	β_5	24.26586	9.314278	**2.61****	0.009
Lnlnadsqr	β_6	-1.437405	.8053548	**-1.78***	0.074
Lnlaborsqr	β_7	-.6013765	.2602831	**-2.31****	0.021
Lncapitalsqr	β_8	-.5222927	.197669	**-2.64****	0.008
Lnfertilzersqr	β_9	-.1305133	.0842936	-1.55	0.122
lnage of coffeesqr	β_{10}	-2.968496	.8024093	**-3.70*****	0.000
Lnlandlabor	β_{11}	.5682658	.4623353	1.23	0.219
Lnlandcapital	β_{12}	.1940248	.596649	0.33	0.745
Lnlandfertilizer	β_{13}	.774223	.3206071	**2.41****	0.016
lnlandage of coffee	β_{14}	-1.968872	.8516247	**-2.31****	0.021
Lnlaborcapital	β_{15}	.2025144	.3011195	0.67	0.501
Lnlaborfertilizer	β_{16}	-.232942	.1197492	**-1.95***	0.052
lnlaborage of coffee	β_{17}	.9091076	.6425335	1.41	0.157

Lncapitalfertilizer	β_{18}	-.0532601	.1150392	-0.46	0.643
lncapitalage of ceffee	β_{19}	-2.437887	.7490371	**-3.25****	0.001
lnfertilizerage of coffee	β_{20}	.1173533	.2703303	0.43	0.664
lnsig2v (variance of idiosyncratic error term/*hfv*)					
Constant	δ_0				
Age	δ_1	.2492087	.3163979	0.79	0.431
Sex	δ_2	-1.078708	2.119984	-0.51	0.611
Experience	δ_3	.0582736	.0710856	0.82	0.412
Education	δ_4	.0058878	.1576465	0.04	0.970
off farm income	δ_5	.1045267	.9974332	0.10	0.917
Credit	δ_6	.5767554	.9855053	0.59	0.558
Distance	δ_7	-.2779156	.2417243	-1.15	0.250
proximity to market	δ_8	.2549488	.096209	**2.65****	0.008
membership in local org	δ_9	.6304792	1.767738	0.36	0.721
slope of the land	δ_{10}	-.5268133	1.17635	-0.45	0.654
Livestock	δ_{11}	.4421414	1.076093	0.41	0.681
cereal crop	δ_{12}	1.01916	1.48323	0.69	0.492
variety of coffee planted	δ_{13}	-1.084071	2.055884	-0.53	0.598
family pressure	δ_{14}	-.234033	.1965735	-1.19	0.234
lnlabor	β_2	-.226984	4.064509	-0.06	0.955
lncapital	β_3	.3470968	4.719297	0.07	0.941
lnfertilizer	β_4	.0353371	8.570047	0.00	0.997
lnage of coffee	β_5				
lnlnadsqr	β_6	-.8059366	1.617182	-0.50	0.618
lnlaborsqr	β_7	-.4996341	.3879305	-1.29	0.198
lncapitalsqr	β_8	-.6731139	.3515821		
lnfertilzersqr	β_9	-.243019	.3030492	-0.80	0.423
lnage of coffeesqr	β_{10}	-1.155619	1.73235	-0.67	0.505
lnlandlabor	β_{11}	.2145934	.7167069	0.30	0.765
lnlandcapital	β_{12}	-.3090533	1.824737	-0.17	0.866
lnlandfertilizer	β_{13}	.2689868	.8815046	0.31	0.760
lnlandage of coffee	β_{14}	-.4594677	1.762715	-0.26	0.794
lnlaborcapital	β_{15}	.9233769	.5072103	**1.82***	0.069
lnlaborfertilizer	β_{16}	.670671	.547039	1.23	0.220
lnlaborage of coffee	β_{17}	.6324153	.8556496	0.74	0.460
lncapitalfertilizer	β_{18}	-.1843202	.9088325	-0.20	0.839
lncapitalage of ceffee	β_{19}	.2344352	1.253109	0.19	0.852
lnfertilizerage of coffee	β_{20}	-1.145197	.884311	-1.30	0.195

*' ** and *** stands for significance of variables at 10%, 5% and 1% respectively

Source: survey result, 2010

Breusch Pagan, Godfrey test for heteroscedasticity

1. Run OLS over stochastic production function and obtain residuals.
2. Calculate the mean error term as $\tilde{\delta}^2 = \frac{\sum e_i^2}{N}$
3. Construct $P_i^2 = \frac{e^2}{\tilde{\delta}^2}$
4. Regress P_i^2 over Z variables (dependent variables/ variables in technical efficiency effects model)
5. Obtain R^2

Based on this test $(N - P) * R^2 \sim X_p^2$ distribution for large sample and where the variable P is the number of independent variables in step four above. The null hypothesis stating homoskedasticity is rejected 5% significance level and 18 degrees of freedom since computed X^2 (44.54) is greater than critical value of 28.87.

Correction of heteroscedasticity

Weighted least square estimation technique is used as following.

$$[lnoutput = \beta_0 + \sum_{i=1}^{n} \beta_i LnX_{ij} + 1/2 \sum_{i=1}^{n} \sum_{k=1}^{n} \beta_{ik} LnX_{ij} LnX_{kj} + \delta_0 + \sum_{1}^{16} \delta_i Z_i + e_i] * {}^{1}/_{\delta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \; 4.1$$

The weighting variable ${}^{1}/_{\delta}$ is obtained from standard deviation of the equation specified in the step four of the Breusch pagan test (refer appendix 2).

Orthogonality Condition

Orthogonality test can be performed as follows for all Z variables:-

$$age = \beta_0 + \sum_{i=1}^{n} \beta_i LnX_{ij} + 1/2 \sum_{i=1}^{n} \sum_{k=1}^{n} \beta_{ik} LnX_{ij} LnX_{kj} + e_i \dots\dots\dots\dots\dots\dots\dots\dots\dots 4.2$$

Table 10 Orthogonality Test

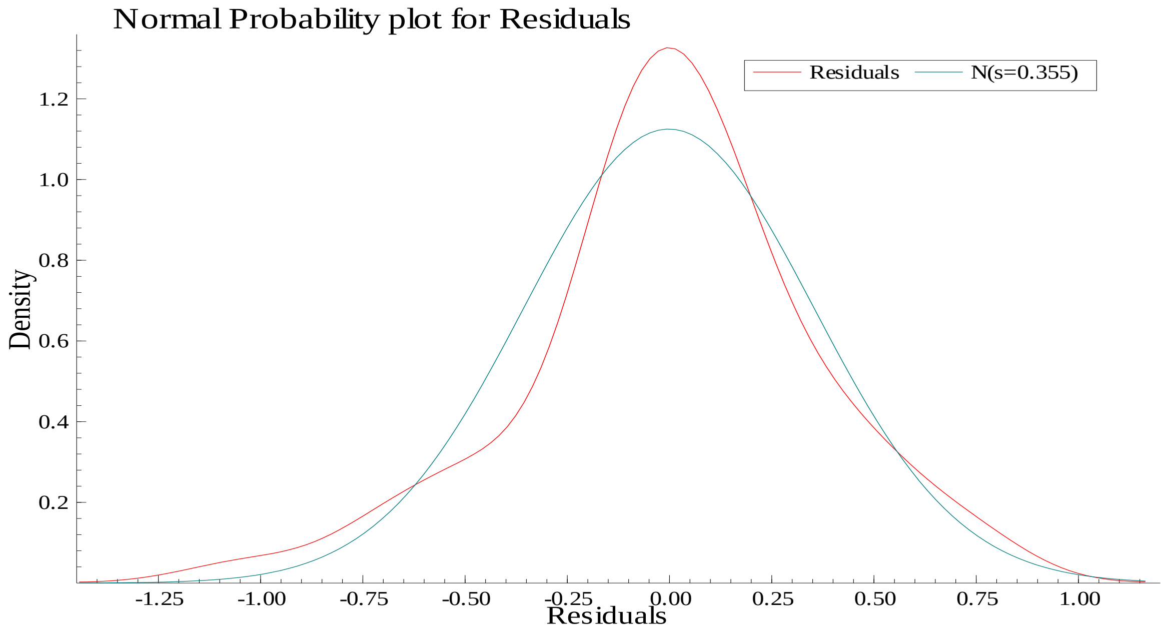
Dependent variable	R^2	Dependent variable	R^2
Age	0.20	Cereal crop	0.59
Sex	0.42	Variety of coffee planted	0.67
Education	0.21	Membership in local org	0.12
Experience	0.49	Slope of the land	0.32
Distance	0.22	Family pressure	0.32
Proximity to market	0.31	Credit	0.15
Livestock ownership	0.58	Off farm income	0.35
medium Soil	0.43	Good soil	0.37
Extension visit	0.23		

Source: Author compilation from the result of rural household survey, 2010

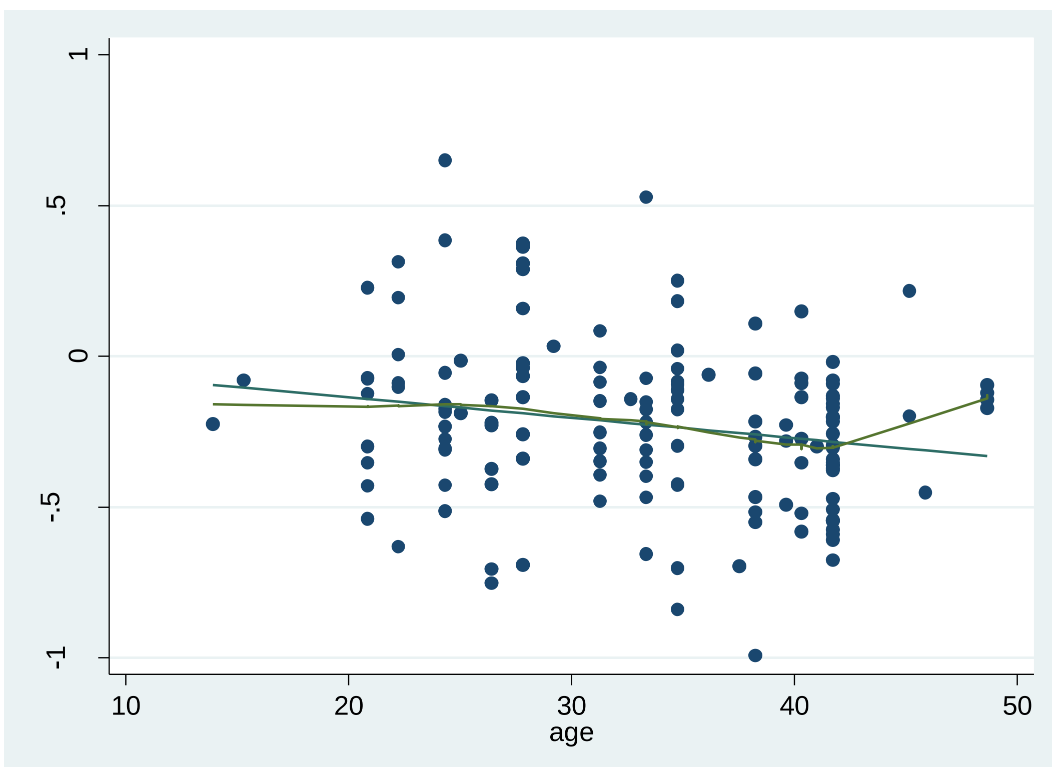
Appendix 3 Multicollinarity test

Explanatory variables of technical inefficiency effects			Cob-Douglas production specification		
variables	Tolerance	VIF	variables	Tolerance	VIF
age	0.493773	2.03	lnland	0.531635	1.88
educ	0.542034	1.84	lnlabor	0.614309	1.63
sex	0.779372	1.28	lncapital	0.569639	1.76
livestock	0.474623	2.11	lnfertilizer	0.812693	1.23
cerealcrop	0.420957	2.38	lnage of coffee tree	0.848641	1.18
poorsoil	0.377786	2.65			
goodsoil	0.575317	1.74			
expriance	0.584529	1.71			
Varietyofcoffee planted	0.605917	1.65			
accesstocredit	0.639620	1.56			
distance	0.651299	1.54			
proximity	0.673322	1.49			
off12700	0.720578	1.39			
familypressure	0.778604	1.28			
extentionvisit	0.795166	1.26			
slopeoftheland	0.808364	1.24			
Mean (VIF)		1.70			1.53

Appendix 4 Normal Probability plot for residual Translg



Non Linearity test



Note: where; Blue: regression line, green: lowess and hence showing absence of nonlinearity.

Appendix 5 Stochastic production function based on the truncated normal distribution

Partial elasticity of inputs is calculated based on this following equation;

$$lnoutput = \beta_0 + \beta_1 lnland + \beta_2 lnlabor + \beta_3 lncapital + \beta_4 lnfertilize + \beta_5 lnage\ of\ coffee\ tree + \beta_6 lnland * lnland + \beta_7 lnlabor * lnlabor + \beta_8 lncapital * lncapital + \beta_9 lnfertilizer * lnfertilizer + \beta_{10} lnage\ of\ coffee * lnage\ of\ coffee + \beta_{11} lnland * lnlabor + \beta_{12} lnlnland * lncapital + \beta_{13} lnland * lnfertilizer + \beta_{14} lnland * lnage\ of\ coffee + \beta_{15} lnlabor * lncapital + \beta_{16} lnlabor * lnlnfertilizer + \beta_{17} lnlabor * lnage\ of\ coffee + \beta_{18} lncapital * lnfert\ ilizer + \beta_{19} lncapital * lnage\ of\ coffe + \beta_{20} lnfertilizer * lnage\ of\ coffee \ldots \ldots 4.3$$

Appendix 6 Technical efficiency estimates by Farmer

Farmer's Code	Technical efficiency	Farmer's Code	Technical efficiency	Farmer's Code	TE	Farmer's Code	TE
1	0.605152	41	0.192283	81	0.870187	121	0.803533
2	0.644093	42	0.631696	82	0.951507	122	0.847746
3	0.376076	43	0.608728	83	0.927703	123	0.874826
4	0.272596	44	0.328488	84	0.971685	124	0.803533
5	0.377412	45	0.454504	85	0.721846	125	0.847746
6	0.802305	46	0.276409	86	0.819977	126	0.874826
7	0.543261	47	0.671102	87	0.590897	127	0.93175
8	0.428449	48	0.644218	88	0.935706	128	0.959317
9	0.418394	49	0.396346	89	0.837393	129	0.951778
10	0.220757	50	0.940567	90	0.966841	130	0.945738
11	0.252604	51	0.714616	91	0.787213	131	0.878057
12	0.705422	52	0.815043	92	0.733735	132	0.953111
13	0.961323	53	0.493965	93	0.923503	133	0.754863
14	0.910189	54	0.716269	94	0.943856	134	0.89511
15	0.857631	55	0.761016	95	0.971203	135	0.688243
16	0.355359	56	0.71041	96	0.886616	136	0.930442
17	0.370846	57	0.982452	97	0.953105	137	0.871728
18	0.245093	58	0.970752	98	0.924254	138	0.945761
19	0.377807	59	0.639886	99	0.904398	139	0.746096
20	0.556442	60	0.957388	100	0.840262	140	0.944594
21	0.544507	61	0.827143	101	0.967821	141	0.823627
22	0.504486	62	0.825653	102	0.902372	142	0.83849

23	0.193617	63	0.941167	103	0.970887	143	0.777559
24	0.312299	64	0.947183	104	0.592651	144	0.904856
25	0.190005	65	0.954396	105	0.823782	145	0.845967
26	0.341716	66	0.933757	106	0.634814	146	0.941818
27	0.252207	67	0.961384	107	0.88547	147	0.952687
28	0.345823	68	0.694949	108	0.804547	148	0.937551
29	0.411751	69	0.880008	109	0.946441	149	0.951527
30	0.33856	70	0.945883	110	0.977559		
31	0.29203	71	0.786672	111	0.952222		
32	0.941369	72	0.937497	112	0.819946		
33	0.474335	73	0.602304	113	0.722066		
34	0.216594	74	0.555314	114	0.879461		
35	0.415526	75	0.617133	115	0.674825		
36	0.632537	76	0.614132	116	0.973142		
37	0.917971	77	0.83164	117	0.959707		
38	0.492821	78	0.738311	118	0.770245		
39	0.344462	79	0.952223	119	0.985293		
40	0.338732	80	0.897682	120	0.972467		

Source: Study Result

Appendix 7 Enumeration Questionnaire

Analysis of factors affecting the Technical efficiency of coffee producers in Jimma zone: A Stochastic Frontier Analysis

Farmer Code___________________

Woreda name ____________________

Kebele name _____________________

Farmer name _____________________

Enumerator name _____________________

General Direction

The enumerators are required to fill the questionnaire according to the direction and training given to them for the last coffee season only for the maintenance of matured coffee trees

The questionnaire has the following three main sections which are categorized in to eleven sub sections;

- section 1 covers information regarding inputs and determinants of technical inefficiencies
- section 2 covers information regarding output
- section 3 covers other related information

Section 1: Information regarding inputs and determinants of technical inefficiencies

1. **Demographic information and other household characteristics**

1.1. Please specify the number of your family size including the house hold head of the family________________

1.2. Please ask the household head regarding their house hold composition including the head of the family and fill in the following table

S.No.	Name of household member	Sex	Age	Years of school ing	Experie nce in coffee farming	[12]Marital status	[13]occupatio n	[10]off farm income	[11]Relation ships with household
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Where;

[10]Amount of off farm income in birr during the last coffee season only.

[11] refer to (1=household head); (2=spouse); (3=son); (4=daughter); (5=any biological Relationships they have with house hold) and (6=non biological relationships).

[12] refer to (1=single); (2=married); (3=widowed) and (4=divorced)

[13] *the main job that each household had during the last coffee season: this refers to farming; trading; service provider; and other*

2. Information regarding livestock ownership

2.1. Please fill the following based on the response given by household head regarding the livestock ownership of the farmer

S.No	Livestock name	number	ownership			
			private	rented	contract	other
1	Oxen					
2	Bulls					
3	Cows					
4	Heifer					
5	Calf					
6	Donkey					
7	Horse					
8	Mule					
9	Goat					
10	Sheep					
11	Chicken					
13	___________					
	Total					

2.2. Did you use animal power for the transportation of coffee output from home to market and from plot to home?

a) Yes b) No

2.3. If yes, fill the following based on the last coffee season if applied on matured coffee tree?

Name of animal	No. of animal used for transporting from plot to home	No. of animal used for transporting from home to market	Cost if hired for only during 2008/9 in birr
Horse			
Mule			
Donkey			
camel			
Total			

3. Information regarding land ownership

3.1. Please fill the following based on the response given by household head during the last coffee season.

S. no	Type of plot allocated	Quantity (in Timad)	Ownership(rented, private)
1	Total land owned		
2	Coffee plot		
2.1	Matured coffee plot		
3	Cereal crop plot		
4	Tropical fruit plot		
5	Spice plot		
6	Forage cultivation plot		
7	Grazing/ pasture land		
8	Fallow land		
9	Natural wood land		
10	Man made wood land		
11	Pulse land		
12	Oil seeds		
13	Vegetables		
14	Root crops		
	total		

4. Use of labor input

4.1. What were the major farming operations you performed in the cultivation of your matured coffee last coffee year?

a) Stumping b) shade regulation c) fertilizing

d) Infilling with self sown seedling e) spraying f) frequent slashing

g) Pruning h) Mulching i) frequent hoeing

j) Harvesting K) other ____

4.2. How many of your family members were participated on the matured coffee maintenance the last 12 months? ______________________

4.3. Fill the following table regarding family labor involved on the maintenance of matured coffee tree during the last coffee season for each operation you did for the last 12 months. (Based on type of operation stated under question 4.1 from a to i)

Family labor	Type of operation	Frequency for each operation	No. of man used	Hrs per day	Total day worked per week(on average
Adult male(15-60)	stumping				
	Shade regn.				
	fertilizing				
	IWSS(d)				
	spraying				
	Freq. slashing				
	pruning				
	mulching				
	Freq. hoeing				
	Harvesting				
Adult female(15-60)	stumping				
	Shade regn.				
	fertilizing				
	IWSS(d)				
	spraying				
	Freq. slashing				
	pruning				
	mulching				
	Freq. hoeing				
	Harvesting				
Child (below 15years)	stumping				
	Shade regn.				
	fertilizing				
	IWSS(d)				
	spraying				
	Freq. slashing				
	pruning				
	mulching				
	Freq. hoeing				
	Harvesting				
Old people (above 60)	stumping				
	Shade regn.				
	fertilizing				
	IWSS(d)				
	spraying				
	Freq. slashing				

	pruning				
	mulching				
	Freq. hoeing				
	Harvesting				
total					

4.4. Did you use hired labor for maintenance of matured coffee tree during the last coffee season (the last 12 months)?

a) Yes b) no

4.5. If yes, how many labor did you hired?_________________ and fill the following table (only applicable for the last 12 months if the farmer used hired labor for the maintenance of matured coffee trees only)

Hired labor	Type of operation	Frequency for each operation	No. of man used	Hrs per day	Total day worked per week(on average
Adult male(15-60)	stumping				
	Shade regn.				
	fertilizing				
	IWSS(d)				
	spraying				
	Freq. slashing				
	pruning				
	mulching				
	Freq. hoeing				
	Harvesting				
Adult female(15-60)	stumping				
	Shade regn.				
	fertilizing				
	IWSS(d)				
	spraying				
	Freq. slashing				
	pruning				
	mulching				
	Freq. hoeing				
	Harvesting				
Child (below 15years)	stumping				
	Shade regn.				
	fertilizing				
	IWSS(d)				

	spraying				
	Freq. slashing				
	pruning				
	mulching				
	Freq. hoeing				
	Harvesting				
Old people (above 60)	stumping				
	Shade regn.				
	fertilizing				
	IWSS(d)				
	spraying				
	Freq. slashing				
	pruning				
	mulching				
	Freq. hoeing				
	Harvesting				
total					

4.6. Did you exchange labor with others for any form of work in coffee cultivation in last coffee season on matured coffee trees?

a) Yes b) no

4.7. If yes, for which jobs did you exchange labor last season?

No.	Type of operation	Hrs worked per day	Total day worked
1			
2			
3			
4			

4.8. How many days of the month, on average, did you work outside your own coffee farm? _______________ Days

4.9. How many days of the month, on average, other than Sundays, you celebrated religious holy days? __________________days

5. Information regarding use of farm tools and implements (agricultural capital)

Please fill the following table by asking the coffee farmer which could be used for maintenance of matured coffee trees (if they owned it)?

agricultural equipment	quantity (in number)	expected life of equipment	unit cost of equipment	agricultural equipment	quantity (in number)	expected life of equipment	unit cost of equipment
Plough				sickle			
sprayer				bucket			
cars				car			
carts				water pump			
sack				bicycle			
hoe				big plastic			
big sieve				table for draying coffee			
basket							
mat							
Total							

5.1. Did any governmental or nongovernmental organization provide you with any form of farm tools and implements?

a) Yes b) no

5.2. If yes, fill the following (only if the farmer took for the last coffee season for the maintenance of matured coffee tree)

agricultural equipment	quantity (in number)	expected life of equipment	If it has cost how much did it cost you during last coffee season

6. Information regarding fertilizer and pesticide (use of modern agricultural inputs)

6.1. What do think are the major problems of your coffee farms?

a) diseases(CBD) problem c) damage by wild animals

b) high tree deaths d) pests

e) Other ______________________; _______________________; _________________

6.2. Please ask the farmers regarding the following input and fill the following table for the information responded during the period of 2008/9 that is used for the maintenance of matured coffee trees?

Types of inputs	Quantity used in Kg	Unit cost in birr	Total cost required in birr for the last year
DAP			
Urea			
Herbicide			
Pesticides			
Fungicides			
Manure which is traditional			
total			

7. Information regarding off farm income and access to credit

7.1. Please fill the following for those farmers who owns matured coffee trees based on the last coffee season status

<table>
<tr><th>source</th><th>Yes/ No</th><th>Amount if yes</th><th>For what purpose is it used</th><th>amount used</th><th>Effect(increase, decrease, no change) on production</th></tr>
<tr><td rowspan="4">credit</td><td rowspan="4"></td><td rowspan="4">Amount & interest rate______&_______ respectively</td><td>1.purchase food item</td><td></td><td></td></tr>
<tr><td>2.purchase other consumer goods</td><td></td><td></td></tr>
<tr><td>3.purchase modern input in coffee production (fertilizer, improved seeds)</td><td></td><td></td></tr>
<tr><td>4.purchase farm tools(for coffee improvement</td><td></td><td></td></tr>
</table>

			5.purchase of fungicides, herbicide,etc		
remittance			1.		
			2.		
			3.		
Self employment			1.		
			2.		
			3.		
Aid/donation					
Family help					
total					

Section two: Information regarding output

8. Output information per plot (production)

8.1. Please ask household head information regarding the following and fill their response in the following table based last coffee season (output information covers only for the last 12 months the farmer got from matured coffee tree) for each coffee plot if the farmer owned more than one plot at different site

plot number	Area in timad	Total output in feresula	Gross output (in birr)	The number CWE[14]	Distance of coffee plot FH[15]	Distance of coffee plot mrt[16]	System of cropping[17]	Fertility of soil[18]	Slope of the land [19]	Ownership of the land [20]	Age of coffee trees
1											
2											
3											
4											
5											
6											
total											

Where;

[14] The number of coffee workers extension visit

[15] refer to the distance of coffee plot from home (total hours it takes)

[16] refer to the distance of coffee plot from market (total hours it takes)

[17] refers to system of coffee farming; mono cropping and mixed cropping

[18] fertility of the soil: good, medium and poor

[19] refers to slope of the land steep which could be steep, medium; flat

[20] fill as "if the plot is private; rented/contract; or other

8.2. Which Type of coffee variety was planted?

a) Traditional coffee variety b) Modern (Java) coffee variety

8.3. Please ask information regarding major crops you were growing last crop season

No.	Type of crop	Area in timad	Production in kuntal	Was production productive	How much of kg is expected to be produced last season	How much of kg is produced last coffee season
1	coffee		____feresula		_____feresula	_____feresula
2	teff					
3.	wheat					
4	maize					
5	Pulse &oil seeds					
6	burley					
7	Vegetable &fruits					
8	total					

8.4. For what purpose you cultivate coffee? (Rank them)

1. Income source 2. for consumption at home

3. Saving (insurance) 4. Social/cultural function 5. Sacrifice/ rituals

6. Risk/ benefit distribution with other animals 6. other___________

Section three: Other related information

9. Information regarding environment

9.1. What are environmental factors affecting your matured coffee farming?

a) Drought b) flood c) Hurricane

d) Temperature e) hail storm e) other ___________________

9.2. Would you pay for any innovation that could reduce soil damage even if it does not increase your income?

a) strongly agree b) strongly disagree

c) Neither agree nor disagree

9.3. Would you contribute more labor for any innovation that could reduce soil damage even if it does not increase your income?

a) Strongly agree b) Neither agrees nor disagrees

c) Disagree

9.4. Wouldn't you adopt any innovation that could cause soil damage even if it could increase my income?

a) Strongly agree b) Neither agrees nor disagrees

c) Disagree

10. Information regarding transaction cost

Fill the following table regarding information about transaction cost for the matured coffee tree during the last coffee season

Type of cost	Unit cost of feresula	Number of feresula produced	Total
Transportation cost from field to home			
Transportation cost from home to market			
Loading cost from the field to home			
Loading cost from the home to market			
Un loading cost from field to home			
Un loading cost from home to market			
Middle men cost			
Total cost in birr			

11. Information regarding social organization

1. Do you have a membership in local organization like Equib, Idir and the like?

    b) Yes b) yes

2. If the response to the above question is yes fill the following table

Name of institution	What is your contribution(birr)	Have you collected money during last coffee season? Yes/No	Amount collected in cash if yes	Amount collected in kind if yes
Iddir				
Ikub				
Mahber				
NGO				
other				
Total				
total				

Thank you very much for your cooperation!!!!