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Technical Efficiency of Smallholder Farmers in Ethiopia: Evidence from Selected Regions

By

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Abstract

This study estimates technical efficiency and identifies inefficiency factors of smallholder farmers in four selected areas in Ethiopia using Ethiopian rural household survey data of 2004. The study classified farmers by their region and selected four villages to estimate their technical efficiency levels. The paper employed stochastic frontier production function to estimate parameters of the frontier function and the inefficiency scores simultaneously using Maximum Likelihood estimation. The empirical results indicate that technical inefficiency characterizing cereal production using translog production function better fits the data from all villages used in this study. Empirical evidence show that the mean technical efficiency ranged from 0.53 to 0.74. An examination of the relationship between technical efficiency and various socioeconomic and institutional variables revealed that formal education, access to credit, number of livestock owned, off-farm income, age and sex of household head and family size were found to be important factors explaining technical efficiency of cereal production in the study villages. However, the importance of these variables in explaining technical efficiency differs across villages. The results suggested that any attempt to improve technical efficiency of farmers should give due attention to these factors and the difference among villages in terms of ecology and institutional factors need to be considered both in an effort to improve efficiency of utilizing the available resources and developing improved technologies in the long run.

Key words: Technical efficiency, stochastic frontier, translog production function, Ethiopia
JEL Classification: C21, C24, Q12, Q14.

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1. Introduction

Accounting for over 40% of GDP, 80% of exports, and 80% of the labor force, agriculture has remained Ethiopian economy's most important sector. Ethiopia has great agricultural potential because of its vast areas of fertile land, diverse climate, generally adequate rainfall, and large labor pool (Degefe et al, 2000). Because of drought, which has persistently affected the country since the early 1970s, a poor economic base (low productivity, weak infrastructure, and low level of technology), and also different regimes' neglect of this sector, the country's agriculture has performed poorly. As a consequence, it has not been able to produce enough food to support the rapidly increasing population. According to Degefe et al. (2001), the growth of the production of major crops was not compatible with the population growth, which clearly required import of food and/or food aid to cope up with the production gap. However, over the last three decades, the importance of Ethiopia's agriculture steadily deteriorated from one period to the next leading to rising poverty and food insecurity.

For a country like Ethiopia that has started sedentary agriculture thousands of years ago, its current inability to feed its population and the continued dependency on foreign food aid to sustain a significant portion of its citizens is a baffling predicament that triggers a broad economic and sociological study (Degefe et al., 2000). The country's overall economic development is intrinsically linked to what happens to the agricultural sector in general and the massive population that resides in this sector in particular. The sheer size of the rural population and the high level of poverty that exists necessitate providing high priority to the sector's rapid development.

The prevailing view among development practitioners is to see the problem of agriculture in developing countries such as Ethiopia strictly as a technical and resource-related problem. This identifies the low level of agricultural productivity as the key problem and the automatic solution that follows is to find ways to enhance productivity. Productivity is essentially regarded as a technological problem. According to Degefe et al. (2000), the technology required is internationally available and what remains to be done is widely diffuse this technology to areas with low productivity. However, one may argue that before diffusing these technologies, they should be subject to at least some modifications since Ethiopia has its own agro-ecological and environmental setup quite different from the rest of the world. The country, therefore, needs technologies that are better adaptable and even generated for its environment than directly diffusing those available in the international market.[1]

It is generally agreed that enhancing productivity in agriculture is the central issue and that technological diffusion is an important piece to this puzzle. However, there is serious doubt about the exclusive focus given to limited technologies such as fertilizers and improved seeds as a determinant of productivity in theory and the effectiveness of such a focus in increasing productivity in practice in countries such as Ethiopia. For instance, issues such as improved land policy, mechanized farming instruments, reducing soil degradation and dependency on rainfall, developing infrastructures and setting up more efficient rural markets are some of the factors that should be given due attention alongside promoting adoption of new technologies.

Today, agricultural productivity in Ethiopia is very low owing to institutional failures, degradation of land and soil, land fragmentation and desertification and other factors. Given the challenges of ever-increasing population and declining per capita food production, increasing productivity is the top priority of the Ethiopian government. Efficiency of production is one factor that determines productivity of farmers. There are a number of factors that determines farmers' inefficiency in Ethiopia. Given the rain-fed nature of the Ethiopian agriculture, some of these factors are beyond the control of the ordinary farmers. Agricultural output can be increased either through introduction of modern technologies or by improving the efficiency of inputs such as labor and management at the existing technology. In other words, productivity can be increased through dissemination of improved technologies such as fertilizer and high-yielding varieties and/or by improving the productive capacity of, say, the farm manager (the farmer). These two are not exclusive because the introduction of modern technology could not bring the expected shift of production frontier, if the existing level of efficiency is low (for example due to the factors at least partly, outside of farmers' control). This implies for the need for the

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[1] They argue that the problem is that these technologies are not available for free and are not cheap. It requires some kind of resource transfer from the rich countries to the poor ones to enable developing countries to acquire both the technological and technical knowhow that goes with it. It also requires poor countries to reallocate their own resources from less productive endeavors towards activities that could help in increasing the productivity of the agricultural sector (Degefe et al., 2000).

integration of modern technologies with improved level of efficiency.

Improving efficiency of farmers is very crucial in achieving sustainable agricultural production and food grain supply, which takes Ethiopia closer to achieving the Millennium Development Goals of the United Nations (UN). It is, thus, both a challenge and an opportunity for Ethiopia to design effective agricultural policies that enable its agriculture-based economy to make the best use of its resources and provide enough food and fiber for its citizens.

The purpose of this study is to contribute to a better understanding of the challenges in agricultural development by estimating smallholder farmers' technical efficiency and identifying factors influencing their technical efficiency. Thus, the study would inform policy makers in designing effective strategies and appropriate policies that will improve the performance of smallholder farmers in Ethiopia. The study would also serve as an input towards understanding factors outside of farmers' control but nevertheless have an adverse effect on their technical efficiency and the need for coordinated policy to tackle such factors.

According to findings from previous studies, e.g. Suleman (1995), Getu et al (1998) and Fekadu et al (2008), undertaken in different regions of Ethiopia, most Ethiopian farmers are technically inefficient, implying that there is a room for improvement through increasing output for the same level of inputs by using the latter more efficiently. In contrary to these findings, Gebreegizeabher et al., (2005), have found that the discrepancy between the observed level of output and the maximum attainable level of output is dominated by random factors outside the control of the farmers rather than their technical inefficiency which tends to be affected by farm management. These studies differ in time, data and places they have studied. Since there can be regional variations in the level of efficiency, the difference in the results of the studies is expected. These discrepancies could also possibly be due to methodological pitfalls that fail to control for unobserved heterogeneities which could potentially bias the estimates, produce inconsistent results and thereby leading to wrong policy conclusions. Furthermore, the studies were based on specific villages or regions and should be considered case by case as there is no control upon which to base comparison among these regions. This study, however, aims to measure efficiency using a cross sectional data with nationally representative sample survey in different agro-ecologies of the country.

It is this absence of universal consensus among economists on the causes of inefficiency that motivated this study to contribute to the debate. In line with this argument, and using a national data, this study attempts to avoid the potential methodological pitfalls mentioned above and will determine if farmers' technical inefficiency in Ethiopia are indeed outside of their controls.

The paper focuses on smallholder farmers producing food crops for two reasons. First, food crops are the most important sector of agriculture both in terms of total agricultural output, the number of people engaged in it and the crucial objective of food security. Secondly, it is the subsector where most of the technology-driven productivity enhancement efforts of the country have been invested in the past two decades under the current government.

The overall objective of this study is to examine technical efficiency of smallholder farmers in different farming systems and agro-ecological regions of Ethiopia and to determine factors affecting farm households' technical efficiency. The specific objectives of the study are (1) to measure of technical efficiency of smallholder farmers, (2) to identify factors causing inefficiency and to determine those beyond farmers' control, and (3) to account for efficiency differential among smallholder farmers in different locations.

The rest of the paper is organized as follows. Section two discusses theoretical framework to estimate efficiency of farmers. Empirical methods and description of data are presented in section three. Empirical results and discussion are presented in section four. Drawing on the empirical results, the last section contains conclusions and policy implications.

2. Analytical Framework

The neoclassical theory of production is based on the notion of efficiency, i.e., firms are efficient and whatever inefficiency comes in the process of production is due to external shocks or statistical noise which is entirely beyond their control. This idea is emphasized in the textbook definition of a production function which gives maximum possible output for given quantities of inputs. One problem with the notion of the maximum is that nobody can recognize it simply by observing the actual level of output unless the observed output is assumed to be the maximum. Such an assumption is implausible since different industries do produce different levels of output even if they use the same level of every observed input. One way of explaining the difference in observed outputs among producers is through differences in productive efficiency (Gebrehiwot, 2005).

When one talks about efficiency one usually means its success in producing as large as possible an output from a given set of inputs, provided that all inputs and outputs were correctly measured (Farrel,1957). Much of the literature on efficiency is based directly or indirectly on the seminal work of Farrell (1957) who argued that efficiency could only meaningfully be gauged in a relative sense, as a deviation from the best practice of representative group of producers. Therefore, Farrell's (1957) consideration led to deviate from estimating 'average' production functions to frontier production function.

Farrel (1957) further decomposes economic efficiency into technical and allocative efficiencies. According to him, technical efficiency is the ability of a firm to produce a certain level of output with a given level of inputs. Technical inefficiency arises when actual or observed output from a given input mix is less than the maximum possible. A producer is said to be technically inefficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output. Thus, a technically-inefficient industry could produce the same output with less of at least one input, or could use the same inputs to produce more of at least one output.

Allocative efficiency is defined as the ability of a firm to choose the optimal input proportions, given relative prices and output (Farrell, 1957). In this sense, allocative inefficiency arises when the input mix is not consistent with cost minimization. In other words, it is the ability of a firm to maximize its profit by equating marginal revenue product of inputs to their respective marginal costs (i.e. equimarginal principle). This follows from individual utility maximization under perfect competition. In particular, a perfect market in factors and products must exist and each firm must be able to predict with reasonable confidence the outcome of each array of production, sales decisions, etc. at its disposal.

2.1 Stochastic frontier approach to measure technical efficiency

The stochastic frontier production function, which was independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), involves unobservable random variable associated with the technical inefficiency of production of individual firms in addition to the random error in deterministic statistical frontiers (Battese and Coelli, 1995). The error term in the stochastic frontier models is composed of a systematic component which captures the effects of measurement error, other statistical 'noise' or random 'shocks' outside the control of the production unit and a one-sided error component which captures the effects of inefficiency relative to the 'best' stochastic frontier. The presence of the variable which captures a firm's inefficiency solves the bounded-range problem encountered in frontier model and the presence of the statistical noise allows the frontier to be stochastic.

The stochastic model may be written as:

$$Y_i = f(\mathbf{X}_i;\beta)\exp(V_i - U_i) \qquad (1)$$

where Y_i is the output of i^{th} farm household; $f(x)$ is a suitable functional form (e.g. Cobb-Douglas or translog) of inputs vector $\mathbf{X}_i$ for the i^{th} farm household and of β which is a vector unknown parameters to be estimated, and U_i is farm-household-specific technical inefficiency which forces Y to be less than or equal to f(x) and V_i is the statistical 'noise'.

In this model, the stochastic production function is $f(X;\beta)\exp(V)$, V having some systematic distribution to capture the random effects of measurement error and exogenous shocks which cause the placement of the deterministic part $f(X;\beta)$ to vary across farm households. Technical inefficiency relative to the stochastic production frontier is then captured by the one-sided error component $\exp(-U), U > 0$. The condition $U > 0$ ensures that all observations lie on or below the stochastic production function.

The basic assumption of the model is that V and U are independent and X is exogenous. Using this assumption, we can obtain direct estimates of the stochastic production frontier model using either maximum likelihood or COLS methods (Forsund et al., 1980). It is important to note that whether the model is estimated by maximum likelihood or by COLS, the distribution of U must be specified.

Stochastic frontier models have been applied to a variety of data sets because of their advantages over the deterministic frontiers by incorporating the two error components. Furthermore, the main attraction of the stochastic frontier model is the possibility it offers for a richer specification. The model also allows for, among other things, a formal statistical testing of hypothesis and the construction of confidence intervals. Because of all these aspects, this model seems most attractive and the study employed the above model using rural farm households cross sectional data to predict technical efficiency.

Following Aigner et al. (1977), the production technology of an economic unit is represented by a stochastic production frontier as follows

$$Y_i = f(x_i;\beta) + v_i - u_i \qquad (2)$$

where Y_i measures the quantity of output of the i^{th} farm household, $\mathbf{x}_i$ is a vector of the input quantities, β is a vector of parameters to be estimated, $f(x_i;\beta)$f(is a suitable production function, v_is are assumed to be independently and identically distributed $N(0, \sigma^2 v)$ random errors, independent of the u_is, and the u_is are non-negative random variables associated with technical inefficiency in food crop production, and are assumed to be independently and identically distributed as half-normal, $u \sim |N(0, \sigma^2 v)|$. The maximum likelihood estimation of equation (2) yields estimates for β and λ where $\lambda = \sigma_v \sigma_u$. The assumptions made on the statistical distributions of v and u, make it possible to calculate the conditional mean of u_i given $e_i = v_i - u_i$.

Technical efficiency of an individual farm household is defined as the ratio of the observed output Y_i to the corresponding frontier output, a point where maximum farm output can be attained in the absence of inefficiency or wastage of any level of input.

The stochastic production frontier model is thus:

$$Y_i = f(\boldsymbol{x}_i;\beta)\exp(\varphi) \qquad (3)$$

where $f(x_i;\beta)$ and $\exp(\varphi)$, respectively, represent the deterministic and stochastic parts of the production frontier, φ represents the random error term, and β is a vector of parameters to be estimated. Φ could be decomposed into its respective two components as:

$$\varphi_i = v_i + u_i \qquad (4)$$

where v is the symmetric error term accounting for random variations in output due to factors outside the farm household, for instance, weather, disease, and bad luck; whereas *u* represents the technical in/efficiency relative to the stochastic frontier and assumes only positive values.

Equation (3) can be re-written as

$$Y_i = f(x_i;\beta).\exp\{V_i\}.TE_i \qquad (5)$$

where $f(x_i;\beta)$ is a deterministic part, which is common to all farm households while $exp\{V_i\}$ is a farm household-specific part, which captures the effect of random noise or shock on each producer. Technical efficiency can then be defined as

$$TE_i = Y_i/(f(x_i;\beta).exp\{V_i\}) \qquad (6)$$

Ratio of observed output to maximum feasible output in an environment characterized by exp $\{V_i\}$. Assuming that f (xi: β) takes the log-linear Cobb-Douglas form, equation (6) can be re-written as:

$$\ln Y_i = ln\, f(x_i;\beta) + v_i - u_i \qquad (7)$$

In this paper, we assume that the frontier technology of cereal production by the sample farm households can be represented by a *translog* production function, and we test against the restricted Cobb-Douglas functional form. The model is specified as:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{4} \beta_j \ln X_{ji} + 1/2 \sum_{j=1}^{4} \sum_{k=1}^{4} \beta_j \ln X_{ji} \ln X_{ki} + V_i - U_i \qquad (8)$$

where the subscripts i (= 1, 2...N) represent i^{th} farm household and ln represents the natural logarithm; Y represents the value of cereal output (in Birr); X_{ji} and X_{ki} are vector of inputs, namely; land, Oxen days, labor, and fertilizer; β_0 ,β_j and β_{jk} are parameters to be estimated; and V_i and U_i are the random variables. V_is are random errors assumed to be identically and independently distributed with N (0, $\sigma^2 v$). The U_is are non-negative random variables associated with technical inefficiency of production. It captures technical inefficiency relative to frontier production.

3. Data Source and Sample Characteristics

A cross section household level data collected in 2004 as part of the Ethiopian Rural Household Survey project, jointly conducted by the Department of Economics of the Addis Ababa University and University of Oxford was used in this study. The project is an integrated rural household survey covering different aspects of the activities of rural households. In selecting the villages, emphasis was given to capture different types of farming systems and to incorporate different agro–ecological regions of the country. All the villages are peasant associations and the sample households were randomly selected from them such that the number of sample households in each PA is proportional to the population size of each Woreda in which the respective PAs are found. In total there were 18 peasant associations in the survey. For this study, smaller number of observations is used than those included in the original data (indicate as to how many villages and households were covered in the survey) due to the removal of observations with missing values for some of the variables included in the study. This resulted in a total of 155 households from four villages in order to determine their technical efficiency and the factors influencing it.

Within each village, random sampling was used, stratified by female headed and non-female headed households. The data is not nationally representative. However, it can be considered broadly representative of households in non-pastoralist farming systems. Different measurement units of each output type in different regions were converted to standard units using conversion factor. Outputs were converted to their monetary value using the price that prevailed at the time the data was collected. Outputs used for this particular study are from the main farming season (*Meher*) in Ethiopia.

The four sites chosen for this study were Yetmen situated in Enemay woreda of East Gojam Zone located at about 248Kms North West of Addis Ababa between the towns of Dejen and Bichena., Garagodo located in Sidamo (Wolayta) area in the southern region, Turfekechemen in Shashemene woreda, in Eastern Shoa zone of Oromia region, and Azdebo located in Kedida Gamela Woreda in Kembata, Alaba and Temboro zone in the Southern Region situated at about 359kms south west of Addis Ababa. Despite some differences in farming system among the sites, oxen plough is the dominant farming technology used in cereal production in all sites.

3.1. Sample characteristics

As shown in Table 1, above 90% of the sample farm households in all four villages male-headed. Average schooling was somewhere between first and first grade in Yetmen and Garagodo while it ranges up to fourth grade in Turfekecheme and Azedebo. Average household size was in three villages was between five and six, the maximum being seven. Average age of the household head was 50 years for all villages considered.

Average value of agricultural products varies among the four villages; Azedebo had the largest average value of output followed by Yetmen. Garagodo and Turfekecheme had the lowest value of 1674.3 and 2701.00 Birr, respectively. Land size was the largest in Turfekecheme, the average being 2.208 ha, followed by Yetmen with average of 1.78 ha. Farm households in Azedebo had, on average, 1.18 ha of land and Garagodo, where the mean land size was the lowest, had 0.95 ha.

Average number of days of labor used in the four villages ranged from seven to eleven. Amount of fertilizer used was the highest in Yetmen where it was 124 kg per household. In the other three villages, amount of fertilizer used per household on average was almost the same.

Households in Yetmen owned on average between two and three oxen while the other three had between one and two oxen per household. Yetmen again had the highest livestock value followed by Turfekecheme, Azedebo and Garagodo. Garagodo and Azedebo had the highest percentage of households with access to credit (about 74%). Turfekecheme was third (62%) while Yetmen had the lowest number of households with access to credit (23%).

Above 80% of households in Azedebo are involved in off farm activity, while the percentage is not that much high for the other three. Turfekecheme has the highest number of extension visits followed by Garagodo and Yetmen, while Azedebo has none.

Table 1: Descriptive statistics of variables used in stochastic and inefficiency models

Variables	**Yetmen**	**Garagodo**	**Turfekecheme**	**Azedebo**
	N= 31	**N=47**	**N=46**	**N= 31**
Sex (= 1 if male)	0.94	0.91	0.90	0.96
	(0.23)	(0.28)	(0.29)	(0.179)
Education (school grade)	1.17	1.44	3.45	3.64
	(2.05)	(2.46)	(3.87)	(3.322)
Household size	5.5	5.34	5.54	6.90
	(1.97)	(2.09)	(2.47)	(2.08)
Household head age	50	49.27	50.58	49.80
	(13.57)	(14.79)	(15.63)	(15.24)
Output (monetary value)	4899.4	1674.3	2701	5979.32
	(3667.37)	(1688.2)	(2331.77)	(8480.55)
Land (hectare)	1.78	0.95	2.208	1.18
	(0.90)	(0.43)	(1.26)	(0.93)
Labor (number of days)	7.08	8.97	11.04	10.19
	(4.05)	(4.58)	(6.65)	(6.10)
Fertilizer(Kg)	124.8	29.28	33.52	31.49
	(79.35)	(20.77)	(46.00)	(25.87)
Number of oxen	2.61	1.55	2.09	1.51
	(0.95)	(0.65)	(1.005)	(0.62)
Livestock (Birr)	3369.56	1277.03	2098.79	1914.58
	(2334.30)	(1154.6)	(2065.31)	(1251.20)
Credit (= 1 if with access to credit)	0.23	0.74	0.62	0.741
	(0.43)	(0.44)	(0.49)	(0.44)
Off farm (= 1 if engaged in off farm activity)	0.14	0.29	0.24	0.806
	(0.35)	(0.46)	(0.43)	(0.401)
Extension visit (Number of days)	0.44	0.8	0.867	0
	(1.74)	2 (2.26)	(2.08)	(6)

Note: N= the total number of observations for the panel in respective villages. The figures in parenthesis are standard deviations.

Source: Own Computation

3.2. Variable definition and hypothesis

lnYi, lnlan, lnlab, lnfert, lnoxen, are output, size of land cultivated, labor, usage of fertilizer, and number of oxen, respectively, which are conventional inputs in a farm household economy. Cross products of these variables will also be estimated in the translog function. All the conventional inputs considered in the equation are hypothesized to affect efficiency of farmers positively, since they are major inputs determining size of output. Age, gender, household size, livestock, education, off-farm activity, credit, extension visits, irrigation, manure and soil conservation activity are the exogenous variables which are chosen based on economic arguments.

Age and age^2 are age category of farmers; the effect of age is hypothesized to be either positive or negative. As the age increases there is an experience effect which can be efficiency increasing. However, to the opposite, as age increases willingness of adopting new technologies and the capacity to do work might decrease. In order to capture these different effects, the two categories of age are specified.

For the variable sex it is hypothesized that female households are expected to be less efficient than male household heads. Education of the household head is anticipated to affect efficiency positively since it will make them open for new technologies. Household size is also expected to have two kinds of effect as when the household has members in a working age which can contribute to its production level, household size will have positive impact on efficiency of the household. On the other hand, if the proportion of the members who are dependent is high, then the effect of household on efficiency can be negative.

Access to credit is anticipated to affect efficiency positively since it will give farmers financial power in order to acquire the necessary inputs they demand. The effect of off-farm activities can be both positive and negative. If there is surplus or unused labor in the household off-farm activity might have an income effect bringing positive effect on efficiency. On the other case, when there is no surplus or unused labor, off-farm activity may take labor away from the farm operations, hence affecting it negatively.

Ownership of livestock can also have either positive or negative effect depending on different situations in which it can be used. If the livestock is used in assisting the farming activity such as using the donkeys to transport their products to the market, using milk for own consumption which will increase family's health and strength, selling and using the money to buy farming inputs, it will have positive impact on efficiency. The other explanation is having if the household has many livestocks it may share the labor and time needed in farming, make the household invest on the livestock rather than farming; hence not leading the household to specialize in the farming. This may affect efficiency of farming negatively.

Extension from the view point it is practiced is expected to help farmers increase their efficiency level. However, from reviewed literature the effect sometimes can be reversed; in most of the cases extension programs couldn't bring improvement in efficiency for reasons like the program being given without programs developed for the introduced technology (Seyoum et al.1998). This negative effect of extension on efficiency, which is in line with Alene (2003), is in contrast with what Mariam et al. (2003) have found for Ada'a and Selale famers; same result was found by Haji (2007) for vegetable-dominated mixed farmers of eastern Ethiopia. Practicing irrigation, soil conservation mechanism and using manure are expected to increase efficiency of production. The activities help farming process so are expected to increase production level.

In this study, we chose to estimate separate production functions for each village considering many differences amongst the villages. Basically, production frontier should be estimated on geographically small, homogenous regions to reduce variability in environmental factors (Sharada Weir, 1999, cited in Hunde 2005). Moreover, use of the entire pooled sample constrains the coefficients on each explanatory variable to be the same across different farming systems which may represent a misspecification and result in biased estimated coefficients (Hunde 2005). That is why in this study we preferred to estimate individual production function for each village rather than combining the data from all villages and estimate an aggregate production function.

The parameters of the stochastic frontier production function and inefficiency models specified above were estimated simultaneously using maximum likelihood method. A Frontier version 4.1

computer programme specifically designed for efficiency estimation developed by Coelli (1994) was used to obtain the maximum likelihood estimates. This programme estimates the variance parameters in terms of $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2/\sigma^2$ under different assumptions of the distribution of the one-sided error term, u. The parameter γ measures the discrepancy between the frontier and observed level of output and is interpreted as the total variation in output from the frontier due to technical inefficiency. It has a value between zero and one such that the value of zero is associated with the traditional response function, for which the non-negative random variable, U_i, is absent from the model while the value of one, shows the absence of statistical noise from the model.

4. Results and Discussion

4.1 Statistical tests

The paper considered various tests of hypothesis about some of the parameters to determine the preferred frontier production function for the five sites. The results of testing various null hypotheses using generalized likelihood ratio test are presented in Table 3.2. Various tests of hypothesis of the parameters in the frontier function and inefficiency model were performed using the generalized likelihood ratio statistic, λ, given by

$$\lambda = -2[lnL(Ho) - lnL(H1)] \qquad (9)$$

where $L(H_o)$ is the value of likelihood function for the frontier model, in which the null hypothesis is imposed; and $L(H_1)$ is the values of the likelihood function for the general frontier function.

If the null hypothesis, H_0, which defines the constrained parameter, is true then the λ is asymptotically distributed as chi-square(X^2) or as mixed chi-square with k degrees of freedom where k is the number of restrictions imposed by the null hypothesis. In other words, k refers to the difference between the number of parameters estimated under the null (H_0) and alternative (H_1) hypothesis. The restrictions imposed by the null hypothesis are rejected when λ exceeds the critical or tabulated value.

The first null hypothesis to test was the selection of appropriate functional form. In order to select the model that better describes the data, the two frontier models namely, Cobb-Douglass and translog frontiers were estimated and the likelihood ratio was computed using equation (7), and this value was compared to the tabulated value to decide the appropriate model. In other words, the null hypothesis is specified in this paper as $Ho: \beta_{jk} = 0$. This states that all the interaction term in the translog function is equal to zero.

Given the preferred functional form for the respective sites, the second null hypothesis performed specifies whether the inefficiency effect are absent from the model (H_o: $\delta_1 = \delta_2 = \ldots = \delta_{11} = \gamma = 0$). Put differently, this null hypothesis specifies that all farmers in the respective sites are operating on the technically efficient frontier and that technical inefficiency effects are zero. Testing this requires the estimation of the model under both the null and alternative hypothesis. Under the null hypothesis, H_o, the model is equivalent to the conventional average production function. The results of the likelihood ratio test shows that this hypothesis is strongly rejected in all sites, suggesting that inefficiency was present in production and the average production function is not an appropriate representation of the data, and the data were better represented by frontier model.

Table 2: Generalized Likelihood Ratio Test of hypothesis for stochastic frontier production function parameters

Null hypothesis	Loglikelihood (H_o)	$X^2cal\ (\lambda)$	$X^2df,0.95^+$	Decision
$Ho: \beta_{11} = \beta_{22} = \ldots = \beta_{34} = 0$				
Yetmen	-24.463	34.3	18.31	Reject Ho
Garagodo	-61.980	24. 67	18.31	Reject Ho
Azedebo	-40. 40	19.79	18.31	Reject Ho
Turfekecheme	-39.83	36.31	18.31	Reject Ho
$Ho: \delta_0 = \delta_1 = \delta_2 = \ldots = \delta_9 = \gamma = 0$				
Yetmen	-60.84	53.38	19.68	Reject Ho
Garagodo	-52.3	30.61	19.68	Reject Ho
Azdebo	-34.31	22.72	19.68	Reject Ho
Turfekecheme	-28.3	47.3	19.68	Reject Ho

A number of applied studies on stochastic frontier production functions have tested the null hypothesis that the simpler half-normal model is an adequate representation of the data, given the specifications of the generalized truncated normal model (Battese et al; 1998). Based on the above tests of hypothesis, we conclude that the preferred model is translog production function and that there is technical inefficiency in all the villages considered in this study. The maximum likelihood (ML) results of the estimation of the parameters of stochastic frontier production and inefficiency effects for each site are presented in Table 3.

4.2. Parameter estimates of the production function

As shown in Table 3, some of the coefficients of the variables in the production function turned out to have unexpected relationships with output. This is mainly the result of multicolinearity problems associated with flexible functional forms such as translog. This is because the translog functional form includes the quadratic form and the cross-product of the existing variables. However, when the purpose of the model is for prediction, as a case of efficiency prediction, multicollinearity will not be a serious problem (Madalla, 1992: 280). Thus, some degree of multicolinearity can be tolerated.

Labor and fertilizer have unexpected sign, with significant statistical value in Yetmen while sign of oxen is as expected but land is not statistically significant. Cross products of labor and oxen, labor and fertilizer, land and oxen, fertilizer and fertilizer and labor and labor have their expected results with significant statistical significance levels. Signs are more as expected in Garagodo than other regions; signs of land, labor, and oxen are as expected while sign of fertilizer turned out to be negative. Among the cross products, land and land, fertilizer and fertilizer and land and fertilizer were found to have the expected signs and significant result.

Land has the expected sign in Turfekecheme while, labor, fertilizer and oxen turned out to be negative. Cross products of labor and labor, fertilizer and fertilizer and land and oxen resulted as expected. Land and labor had a negative coefficient in Azdebo, while fertilizer and oxen resulted as expected. Cross products of land and land and labor and labor were also found to be positive and statistically significant. Although the difference of the results in the respective regions can be explained according to each village's economic activity, below is stated theoretical and empirical explanation of the results found.

The unexpected coefficient of labor might have occurred due to various reasons. First there might be error in measurement of the input. In this study, we used potential family and hired labor to roughly proxy labor used in production. This might have obscured the effect on output of labor as other source of labor such as shared labor and children's labor are excluded. The second possible reason which is related to the first one is that the effect of potential labor on output depends on the availability of cultivable land. Put differently, households with high potential labor may not produce more, given very small size of land holding and in the face of the prevalence of unemployment or underemployment in rural Ethiopia. It is not uncommon to find negative coefficient of labor in production. Battese and Broca (1997), as cited in Hunde (2005), found a negative elasticity of output for labor for Pakistan and various explanations were given. According to the study the negative elasticity of frontier output for labor indicates either labor use in their study area was not optimal or the frontier model estimated was not econometrically satisfactory. Negative elasticity of labor is also found in other study of Ethiopian farmers (Abrar, 1996:19).

The insignificance of oxen might explain the less scarcity of this farm input among the sample farmers. The other important variable in the production of cereal is animal traction power that is proxy by oxen ownership[2] in this study. The coefficient is positive and statistically significant at 10% level. Although ownership of oxen may not correctly represent the amount of oxen days or animal power used in the production, it has a considerable influence on the availability of animal power on time. Farmers who do have their own oxen are able to use them at the right time whenever needed, while those without oxen have to wait for some time until the animals are free so that they may borrow them. Thus, the positive and significant coefficients of this variable may explain the relative advantage of being owner of oxen in preparing land on time.

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[2] We had some zero values for this variable. Thus, in order to facilitate taking logs, a constant one was added to this variable before transforming it into logarithm, as is common practice (Jacoby, 1992 as cited in Weir, 1999).

The result for fertilizer application also seems puzzling when one observes the role that fertilizer is expected to play in boosting production. However, this is not unrealistic. It is well understood that a mere application of fertilizer may not lead to high production. For fertilizer to have a significant impact on production, the recommended amount has to be used along with other yield augmenting inputs such as improved seeds, and at the right time. Furthermore, according to Croppenstedt and Mulat (2003), the effects of chemical fertilizer largely depend on the prevailing weather condition, timely delivery and application. Empirical evidences have also shown high degree of inefficiency in the utilization of fertilizer in Ethiopia in general. Hence, the coefficient of fertilizer might have explained this fact.

4.3 Technical efficiency estimates

The results of the maximum-likelihood estimation presented in Table 3 show the presence of technical inefficiency among cereal producers in the sample villages. The estimate of discrepancy parameter, γ indicates the proportion of the one-sided error component in the total variance of the composed error term. In other words, γ measures the effect of technical inefficiency in the variation of observed output relative to frontier output.

Consequently, the coefficient of γ was found to be 0.99 for Yetmen, Garagodo, and Turfekecheme, while it was 0.17 for Azdebo. These values indicate that the variation between actually realized output level and the frontier output level due to technical inefficiency within farms in Yetmen, Garagodo, and Trufekecheme, are about 99 percent, and 17 % for Azdebo.

The predicted technical efficiency values for sample farmers in Yetmen vary from 0.40 to 0.99, with mean of 0.74. These results indicate that there was high variation in technical efficiency among farmers. It implies that given the existing resources and available technology, cereal output could have been increased, on average, by 74 percent in the period investigated.

Table 3: Maximum-Likelihood estimates of translog stochastic frontier production function

Variables	Parameter	Coefficient			
		Yetmen	**Garagodo**	**Trufe Kecheme**	**Azedebo**
Stochastic frontier model					
Constant	β_0	18.2 (11.1)*	6.8 (1.81)*	12.56(7.05)*	8.5(6.27)*
Ln (L)	β_1	0.9 (1.02)	2.2 (1.55)**	1.08(1.10)	-0.11(-1.2)
Ln (Lab)	β_3	-4.8 (-6.26)*	4.8(1.10)	-3.8(-3.00) *	-3.2(-1.74) *
Ln (Fert)	β_4	-3.7(-5.7)*	-2.4(-2.1)*	-1.9(0.83)	0.94(1.0)
Ln (Ox+1)	β_2	6.6 (8.9)*	3.6 (1.6)**	-1.1 (-1.71)*	(0.21) (0.22)
Ln(L)*Ln(L)	β_{11}	-1.4(-9.6) *	0.44(1.6) **	-0.16(-0.49)	(1.9) (3.7)*
Ln(Lab)*Ln(Lab)	β_{22}	0.62 (5.8)*	-0.012(-1.9) *	1.1(4.9)*	1.04(2.04) *
Ln(Fert)*Ln(Fert)	β_{33}	0.53(6.7) *	0.52 (1.46)**	0.15(5.2)*	0.014(0.06)
Ln(ox+1)*Ln(ox+1)	β_{44}	-2.2 (-39.4)*	-0.85(-0.86)	0.43(0.99)	0.86(0.78)
Ln(L)*Ln(Lab)	β_{12}	-0.17(-1.11)	-0.81(-1.4)	-0.5(-1.0)	-0.12(-0.20)
Ln(L)*Ln(Fert)	β_{13}	-0.73(-4.3)*	0.42 (1.48)**	-0.1(-1.10)	-0.13 (-0.26)
Ln(L)*Ln(ox+1)	β_{14}	5.3(95.8) *	-1.3(-1.0)	0.84 (1.43)**	-0.45(-0.43)
Ln(Lab)*Ln(Fert)	β_{23}	0.38(4.4) *	-0.58 (-1.48)**	-0.22(-3.4)*	-0.26 (-0.61)
Ln(Lab)*Ln(ox+1)	β_{24}	0.96(10.14)*	-0.54(-1.14)	-0.38(-0.78)	-0.13(-0.17)
Ln(Fert) *Ln(Ox+1)	β_{34}	-1.6(-10.5)*	-0.94(-1.317)	0.039(0.05)	0.016(0.03)
Inefficiency effects model					
Sex	δ_1	-0.25(-0.26)	8.6 (3.2)*	1.3 (1.5)**	-3.0(-1.5)**
Hhsize	δ_2	0.35(1.8)*	0.86 (1.4)**	0.14(1.33)**	-0.38(-1.36)**
LVSK	δ_3	-0.003(-1.5)*	-0.0048(-1.4)**	-0.014 (-8.1)*	-0.0071(-2.05)*
Age	δ_4	-0.09(-1.3)	-0.16-0.8	0.07(1.3)	0.34(2.01)*
Agesqr	δ_5	0.015(2.2)*	0.018(0.86)	-0.0043(-0.88)	-0.03(-1.8)
Edu	δ_6	-0.49(-1.1)	0.21(1.9)*	-0.06(-0.7)	-0.02(-1.4)**
Offarm	δ_7	-1.2(-1.24)	-1.7(-3.5)*	0.47(0.87)	-0.69(-1.03)
Cred	δ_8	-1.8(-2.07)*	-2.0(-3.2)*	-0.22(-0.56)	0.15(0.18)
Ext	δ_9	0.73(2.5)*	-1.3(-3.1)*	-0.1(-0.54)	-0.31(-2.0)*
Variance parameters					
Total variance= $\sigma2u+ \sigma2v$	$\sigma2$	0.80(4.7)*	3.9 (3.3)*	0.82(3.99)*	0.52(2.9)*
Variance Ratio= $\sigma2u/ \sigma2$	γ	0.99(469.8)*	0.99(393.76)*	0.99(513)*	0.17(1.15)
Loglikelihood Function		-2.4	-52.3	-28.26	-34.3
Mean technical efficiency		0.74	0.47	0.49	0.53
No. of observations		31	47	46	31

Note: * and ** indicate significance levels at 5% and 10%, respectively. Figures in parenthesis are estimated t-ratios.

Source: Own computation

Table 4 shows that in Yetmen, no farmer fell in the lowest efficiency range (<0.30) while, 42 percent of them were in the highest efficiency range (0.91-1.00). In Garagodo, the efficiency level ranges from 0.11 – 0.99 with mean efficiency of 0.47. Equal number of farmers fell in the lowest and highest efficiency range, 32%.

Table 4: Frequency distribution of technical efficiency of individual farm households

Efficiency interval	Peasant Association			
	Yetmen	Garagodo	Turfekecheme	Azedebo
< 0.30	0	31.91	6.52	19.35
0.31 – 0.40	0	6.38	13.04	9.67
0.41 – 0.50	16.12	6.38	10.86	3.22
0.51 – 0.60	9.67	6.38	10.86	3.22
0.61 – 0.70	3.22	4.25	12.76	6.45
0.71 – 0.80	9.67	6.38	8.69	12.9
0.81 – 0.90	9.67	4.25	13.04	16.12
0.91- 1.00	41.9	31.91	21.73	16.12
Mean	0.74	0.47	0.49	0.53
Maximum	0.99	0.99	0.98	0.96
Minimum	0.40	0.11	0.15	0.10
Number of observation	31	47	46	31

Source: own computation

The number of farmers is almost equally distributed over the different efficiency ranges in Turfekecheme with mean efficiency of 0.49. The highest number of farmers is found in the highest range of 0.99-1. The highest number of famers is found in the lowest efficiency range in Azdebo with mean efficiency of 0.53.

4.4 Sources of technical inefficiency

Given the differences in efficiency among farmers, it is appropriate to ask why some farmers achieve a relatively high efficiency score whilst others are less efficient. Thus, investigation of the factors behind the variation in technical efficiency of cereal production or identification of the sources of technical inefficiency was another prime concern to this study.

The estimates for the parameters of inefficiency models for each site are given in Table 3 together with estimates of frontier production function. It should be noted that since the explained variable in the inefficiency function is the inefficiency, a positive sign on a parameter indicates that the associated variable has a negative effect on efficiency and a negative sign indicates a positive efficiency effect.

As can be seen from the results, most of the coefficients have the expected signs. However, some have turned out to have unexpected signs in some villages. In fact, this is likely to happen in the face of relatively different settings in which the farmers in study sites operate. In other words, one should not always expect a variable to have the same effect on farmers operating under different circumstances.

The coefficient of sex of a household head in Yetmen and Azdebo is negative, as was expected. This indicates that male-headed households are relatively more efficient than their female-headed counterparts. However, the same variable was found positive for Garagodo and Turfekecheme. This might be due to the village's culture of no discrimination against females.

The result showed that the positive relationship of family size and technical inefficiency in Yetmen, Garagodo and Turfekecheme support the argument that farm households with larger members tend to be less technically efficient than those with a smaller number of people to feed. This may be due to the existence of unemployment or underemployment in rural Ethiopia which makes most of household labour underutilized. A positive and significant effect on technical inefficiency of family size was also reported in other similar studies (e.g., Abrar, 1996). The result was unexpected for Azdebo village and it was statistically significant.

Livestock holding is used as a proxy to the wealth position of a household in this study. As expected, livestock holding is found to negatively influence technical inefficiency in all the four villages at the conventional statistical significance levels, indicating that households with large number of livestock (in TLU) are more technically efficient than those with small number of livestock.

Age, in this study, is used to proxy farmer managerial experience and we would expect a farmer with higher age to be more technically efficient. The result, however, did not support this, as age seems to have no effect on technical efficiency of the farm households. It was expected that a positive coefficient on age in the inefficiency function suggests that farmers are less efficient as they age, but the negative coefficient on the age squared indicates that technical efficiency declines at a falling rate as the head gets older. A surprising result for the age variable was that while the variable was insignificant at level, its squared term was significant in some cases.

For sample households in Trufekecheme and Yetmen, education level of household head did not significantly explain the variation in technical efficiency across farmers in these villages. The possible explanations for weak relationship between education and technical efficiency in Trufekecheme and Yetmen may be due to measurement error related to education variable. In this paper, we constructed education variable as a dummy, one representing those households' heads who attended at least primary education, and zero otherwise. This implicitly assumes all levels of formal education to have the same effects on efficiency. However, evidences elsewhere and in Ethiopia have shown different effects on efficiency and productivity of different levels of education of a household head. Wubneh and Ehui (2006) found that literacy and livestock holding training significantly affected dairy farmer's efficiency.

The coefficient of off-farm activity has got negative sign for all sites except Turfekecheme implying that technical inefficiency decreases as the value of this variable increases. In other words, off-farm income is positively associated with technical efficiency suggesting that obtaining off-farm income increases technical efficiency of production. This may be because off-farm income improves access to additional capital and facilitate timely acquisition and application of the necessary agricultural inputs. The implication of this result is that policies encouraging off-farm activities would improve technical efficiency of farmers. The insignificance of off-farm income with technical efficiency in all sites except in Garagodo, might be that the level of off-farm income obtained was low to bring about meaningful impact on efficiency.

Credit has negative coefficient, as expected, with the exception in Azdebo, where it turned out to have positive coefficient. The negative coefficient indicates credit availability tends to reduce technical inefficiency. For farmers in Yetmen and Garagodo the coefficient is significant suggesting the importance of credit in explaining the variation in technical efficiency among farmers. The result further shows that credit may play a key role in reducing technical inefficiency through mitigating the cash constraints the farmers face and enabling them to acquire purchased inputs timely that they could not otherwise afford with their own resources.

The possible explanations for insignificant effect on efficiency of credit in Trufekecheme and Azdebo may be that: first, farmers might have used credit for other purposes than agricultural activities for which the loan might have borrowed; secondly, the mount of credit may also matter, i.e., the expected effect of credit may not be realized if the loan size is too small; finally, the insignificant influence of credit might have attributed to poor managerial skills of farmers.

The coefficient of extension visit on inefficiency model is found to be negative in all sites except in Yetmen. The negative coefficient implies that extension visits would improve efficiency level of farmers. The result was found to be insignificant in Turfekecheme. The possible reason might be that the small number of visits in the village and the minimal effect of extension when applied to a farm which is not adequately given with modern agricultural technologies. The unexpected result in Yetmen is not uncommon since the result can happen in areas where extension visits contribute not to the improvement of farmers' efficiency rather to depletion of their efficiency. In this connection, Alene (2003) argues that extension program has failed in enhancing the productive efficiencies of farmers in Meta and Babile districts, where he found no positive impact on the productive efficiencies of farmers. This negative effect of extension on efficiency is in contrast with what Mariam et al. (2003) has found for Ada'a and Selale farmers. The same result was also found by Haji (2007) for vegetable-dominated mixed farmers of eastern Ethiopia. Another study by Seyoum et al (1998) revealed that extension only brings positive effect when it is provided for farmers in a development program projects.

5. Conclusions and Policy Implications

5.1. Conclusions

Agriculture is Ethiopia's most important economic sector. However, its performance has not been satisfactory in the past though the sector had always played an important role in economic growth and development. Several reasons can be cited for its low productivity among which inefficiency in the use of the available resources may be one. This study has aimed at estimating the level of technical efficiency and examines the potential to increase output without additional inputs and attempts to identify the factors that may influence technical (in) efficiency of smallholder cereal production.

The data used in this study have come from the Ethiopian Rural Household Survey conducted in 2004 by the Department of Economics of Addis Ababa University, in collaboration with other institutions. The study employed stochastic frontier production function to the data from four of the villages covered in the survey during this period. For each village, a test was made to identify whether Cobb-Douglas or translog production function is appropriate model. The result shows, based on likelihood ratio test, that the translog production function is appropriate for all villages considered in the study. Given the functional form, a hypothesis of no technical inefficiency was also tested and rejected for all villages. Thus, the average production is not a suitable model to explain production behavior of the farmers. In other words, there exists inefficiency differential among farmers in the study areas and hence the stochastic frontier model is the appropriate model.

The results of farm-level technical efficiency show that there are opportunities to increase output by improving technical efficiency of farmers in the study areas as the discrepancy of observed output from the frontier output in most cases attributed for the differences in the ability to utilize the available resources. The mean technical efficiencies of the farmers in Yetmen, Garagodo, Trufekecheme and Azdebo were 0.74, 0.47, 0.49 and 0.53, respectively. This indicates that there were substantial inefficiencies in cereal production in the study areas and cereal output could be increased, on an average, by about 26% in Yetmen, 53% in Garagodo, 51% in Trufekecheme, and 47% in Azdebo. The result further shows wide variation in technical efficiencies across farmers within a village.

An examination of the relationship between technical inefficiency and various socioeconomic and institutional variables revealed that household size, livestock, age square and credit were important factors explaining the variation in technical efficiency among farmers in Yetmen. For farmers in Garagodo, sex of the household head, education of household head, household size, livestock, off-farm activities, credit and extension were found to be important factors influencing technical efficiency. The result for Trufekecheme shows that sex, family size, livestock holding were important in explaining the discrepancy between the actually realized and frontier output and the differences in technical efficiency among farmers. Age, education level of household head, sex, family size, livestock holding, and extension visits were important factors for farm households in Azdebo.

5.2. Policy implications

Based on the results of this study, some policy implications can be forwarded, although conclusive policy recommendation may require a more detailed analysis, possibly on extensive set of panel data with large sample size than this study considers.

The wide variation in the level of efficiency among farm households in the study areas indicates that there is high opportunity for these households to raise their level of output using just the existing inputs and available technology. The policy implication of this is that future agricultural policies should improve the capacity of farmers to apply the available technology more efficiently. The results also suggest that efforts to improve the productivity and efficiency of smallholder farmers need to consider differences in agro-ecology among farmers and farm specific socioeconomic factors rather than pursuing a single nationwide policy.

The significance of education level of household heads in Azedebo and Garagodo signifies that education can be an important policy tool to improve efficiency of farmers. Therefore, due emphasis should be given to the expansion of adult education in rural Ethiopia so that farmers may produce more efficiently given their resources and available technology.

The results also point out that credit availability and off-farm income enhanced technical efficiency although in some villages the relationships are found to be weaker and had unexpected sign. Thus, policies and strategies that promote the establishment and expansion of rural microfinance institutions and that create alternative employment opportunities in rural areas would be crucial to bring about considerable economic gains in terms of increasing output with the available technology and resources. In addition to mitigating farmers' liquidity constraints at times of critical farming operations, creating alternative employment opportunities may reduce pressure on land and may raise labor productivity thereby help increase technical efficiency.

The significant effect of livestock holding on cereal production in all the villages considered shows that farmers in the study areas practice integrated livestock-crop production system and making available the necessary input on time at the required amount better positions wealthier farmers. The implication is that efforts to increase productivity and efficiency should pay attention to the crop-livestock interaction in the farming systems. For instance, it is important for research to consider such interaction while also developing technologies.

Finally, as the results suggest, there exists a potential to increase cereal production through improving efficiency of utilizing the existing resources. Farmers' efficiency can be improved through better use of the existing resources and also introducing and promoting new technologies. Development and promotion of technologies should focus on the specific agro-ecological conditions of different areas in order to improve efficiency of the farmers in those areas.

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DECLARATION

I declare that this Project Report is my original work and has not been presented for a degree in any other University and all the sources of materials used for the thesis are duly acknowledged.

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This Project Report has been examined and approved as fulfilling the required standard.

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