Analysis of Technical Efficiency of Crop producing Smallholder Farmers in Tigray,Ethiopia.

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7 June 2011

Analyzing Technical Efficiency of crop producing smallholder farmers in Tigray region, Ethiopia .Stochastic Frontier Analysis

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ABSTRACT

This paper provides new estimates of small holder farmers' technical efficiency and its principal determinants using a rural Tigray micro finance survey data collected in 2009. Both descriptive and econometric methods are used. The hypotheses tests confirm the adequacy of Cobb-Douglas over Translog frontier; the appropriateness of using SFA over OLS; the joint statistical significance of inefficiency effects; the appropriateness of using truncated normal distribution for one sided error; and the increasing returns to scale nature of the stochastic production function.

The maximum likelihood parameter estimates showed that except labor all input variables have positive and significant effect on production. The results reveal that number of oxen owned has the highest elasticity, then land, followed by labor and value of farm equipment. The analysis shows that the mean technical efficiency of farmers is 60.38% implying that output in the study area can be increased by 39.62% at the existing level of inputs and current technology by *operating at full technical efficient level.*

The estimated stochastic frontier production function revealed that all determinants (except households' sex, farm size, participation in irrigation, and member to association) have significant effect on efficiency of farmers. The sign of coefficients of determinants is found as the expected, except households' sex. Education of household heads, family literacy, family size, share cropping, credit access, crop diversification, and land fertility are found to enhance efficiency. In contrast, Households' age, dependency ratio, livestock size, and off-farm activity are found to increase inefficiency.

Key words: **Ethiopia, Technical Efficiency, Smallholder Farmers, Agriculture.**

Introduction

1. Background

Empirical studies on the analysis of efficiency of smallholder farmers have been influenced by Schultz's (1964) 'poor-but-efficient hypothesis'. If smallholder farmers in backward agricultural settings are reasonably efficient, as advocated by Schultz, then increase in productivity will require new technologies to shift the production frontier upward. However, this is true when they produce under the same conditions and have enough time to aware the new technologies. This implies that after the introduction of new technologies, it may take a long time before they adopt and learn to use the technologies efficiently. As a result, this hypothesis has brought much debate in Sub-Saharan Africa (Owuor and Shem, 2009). Hence, given the case that developing countries have scarce resources to undertake new investments on modern technologies to increase agricultural productivity and production, improving the efficiency of inefficient farmers has a paramount importance (Bakhsh, 2007 and Al-hassan, 2008).According to World Bank (2007) agriculture has accounted for about 30 % of Africa's GDP and 75 % of total employment. Over 90 % of African agricultural production highly depends on rain-fall. This reveals the fact that erratic rainfall patterns have challenged crop production in these areas and this will be further worsened by climate shock which is expected to increase rainfall variability in many African countries.

Currently Ethiopia is the second most populous country in Africa, with a population of almost 74 million and growing at a rate of 2.5% per annum (CSA, 2008). According to World Food Program (2009) economic growth of the country highly depends on the agricultural sector, which accounts for 47% of the GDP and more than 90% of exports, and 83% of the total employment, followed by the service and the manufacturing sectors with a share of 39% and 14% of GDP, respectively. The agriculture sector in Ethiopia is highly dependent on rain-fall and thus more vulnerable to weather shocks. Extreme dependence on traditional technology, rain-fed agriculture, poor supplementary services such as access to extension, credit, marketing, and infrastructure, and poor agricultural policies have been the principal causes of food insecurity in Ethiopia.

Despite significant share in the GDP of the country, agriculture sector lacked the required attention in the country's development goals in the past. One of the significant policy changes since the period of transformation in 1992 has been the greater attention placed on improving the production and productivity of smallholder agriculture through higher usage of modern agricultural inputs. As part of the agricultural development-led industrialization strategy (ADLI), the existing government of the country encouraged and adopted New Extension Program (NEP) like adopting output rising improved inputs and made them accessible to the farmers.

In spite of the potential benefits that may be gained by proper identification of the extent, causes and possible remedies of technical inefficiency of farmers, available evidence shows that little attention has been given to a systematic analysis of the efficiency of resource use in Ethiopian in general and in the study area in particular. Therefore, such studies will benefit farmers as policy intervention may need to have prior information whether to continue with the existing technology by improving the efficiency of less efficient farmers or to introduce a new technology so as to increase crop production in the study area.

2. Statement of the Problem

Although agriculture still remains to be the back bone for Ethiopian economy, its performance has been unsatisfactory and unable to fulfill the growing food demand as result of high population growth. Now a day this decline in productivity has been given due attention in the national development efforts. However, because of the influential 'poor-but-efficient hypothesis' of Schultz (1964) resources have been concerned mainly with increasing the productivity of agriculture sector by the introducing and adopting new technologies. Thus, due to limited use of modern inputs investigating the potential of increasing agricultural production through improving technical efficiency of farmers appears to be another important source of productivity growth (Kinde, 2005).

Now a day in Ethiopia there has been increasing focus by policy-makers on investments on modern technologies rather than efforts targeted at improving the efficiency of inefficient farmers. Theoretically, introducing modern technologies can increase agricultural productivity and production. However, in areas where there is inefficiency in which the existing inputs and technologies are not efficiently utilized trying to introduce new technologies may not have the expected results. Obviously, the level of farmers' technical efficiency has paramount implications for country's choice of development strategy (Zenebe et.al, 2005).

Yet empirical works on the farm level of technical efficiency is limited and knowledge of farmers' production situations remains inadequate particularly in Sub-Saharan Africa. Hence, given the case that developing countries have scarce resources to undertake new investments on modern agricultural technologies, improving the technical efficiency of farmers is indispensable i.e. there is a wide room for increasing agricultural productivity and production in these areas by improving technical efficiency of farmers at the existing resources (Al-hassan, 2008). Furthermore, from the perspective of formulating effective agricultural policies, undertaking empirical works on farm level technical efficiency has paramount importance in providing valuable information to policy makers which will be used to enhance agricultural productivity. Equally important is to examine the principal factors that affect technical efficiency of farmers, since these factors can be influenced by public policies.

Similarly in Ethiopia, researches on technical efficiency of smallholder agriculture are not extensive, and the findings or conclusions of some of them are not consistent with one another. Therefore, policy implications drawn from some of the above empirical works may not allow in designing area specific policies to be compatible with its socio-economic as well as agro-ecologic conditions and the results of some of the studies may not allow to make comparative analysis of farmers' efficiency across tabias[1]. Therefore, this study intends to fill these gaps.

The objective of this study is to make analysis of technical efficiency of smallholder farmers with the aim of providing information to policy makers whether to continue with the existing technology by improving the efficiency of less efficient farmers or to introduce a new technology so as to increase crop production in the study area.

3. Working Hypotheses

Smallholder farmers are characterized by heterogeneity in various aspects of livelihoods like differences in resource endowments, knowledge of farming practices, and other socio-

[1] Tabia is local administrative area equivalent to Kebele

economic factors which could lead to difference in their technical efficiency. The following hypotheses can be tested using the generalized likelihood ratio test: LR = -2[L (H0)-L (H1)], where L (H0) and L (H1) are the values of log likelihood functions under the null and alterative hypothesis, respectively (Greene, 1980). The null hypothesis is rejected when the calculated chi-square is greater than the critical chi-square with degree of freedom (the number of parameters equal to zero at null hypothesis) at 1%, 5% or 10% level of significance i.e. LR > χC^2 (Kodde and Palm, 1986).

1. The hypothesis that identifies the appropriate functional form that can adequately represent the data between Cobb-Douglas and Translog production function is tested.
2. The hypothesis that shows the appropriateness of employing stochastic frontier model over ordinary least square (whether technical inefficiency effect present in the model or not) is tested. The test is based on the statistical significance of the parameter gamma, γ. This helps to achieve the first specific objective of this study i.e. to measure the level of farm specific technical efficiency and whether the farmers in the study area are technically efficient or not.
3. The hypothesis that specifies whether the technical inefficiency effects are jointly significant or not is tested. This helps to achieve the second specific objective of this study i.e. whether the inefficiency effects are significantly responsible for efficiency variation among the farmers in the study area or not.
4. The hypothesis that specifies whether the half-normal distributional assumption of inefficiency effect is appropriate or nor is tested. If the null hypothesis is rejected, then truncated-normal distributional assumption of one sided error term is more appropriate.
5. The hypothesis that specifies whether the stochastic frontier production function is characterized by constant returns to scale or not is tested. If the null hypothesis is rejected, -then looking the sum of all inputs elasticity of output it is possible to decide whether the returns to scale is decreasing or increasing.

4. Literature Review

Most of the empirical works on the efficiency of small holder farmers have been triggered by Schultz's (1964) 'poor-but-efficient hypothesis'. According to Schultz (1964) small holder farmers in backward agricultural settings are poor but efficient in allocating their resources. If farmers are efficient, then increase in productivity will require new inputs and technology so as to shift the production frontier upward. In addition, there is a possibility to enhance productivity through more efficient use of farmers' resources with the given technology (Zenebe.et.al, 2005).

The classical theory of production is based on the notion that firms are efficient and any actual output variation from the frontier is due to external shocks which is entirely beyond the control of the decision makers. According to neo-classical theory of production different producers can produce different levels of output even if they use the same level of inputs and technology. The difference in observed outputs from the frontier among producers can be explained not only from external shocks but also through differences in efficiency of using the existing resources.

Most often, many scholars used productivity and efficiency interchangeably and consider both as the measure of performance of a smallholder farmers. However, these two phenomena are not the same (Coelli et al., 1998). In simple term, productivity of farmer is producing a given level of output per unit of input. Productive efficiency represents the optimal input mix to produce any given level of output that minimizes the cost of production (Forsund et al., 1980). Productive efficiency consists of technical and allocative efficiency.

Technical efficiency measures the relative ability of the farmers to get the maximum possible output at a given level of input or set of inputs. Technically efficient farmers are those that operate on the production frontier which represents maximum output attainable from each input level. All feasible points below the frontier are technically inefficient points. According to Ellis (1988) technical efficiency is the extent to which the maximum possible output is produced from a given set of inputs. On the other hand, a producer is said to be allocatively efficient if production occurs in a set of economic region of the production possibility set. Thus, if a farmer has achieved both technical and allocative efficiencies, then the farmer can be said economically efficient.

Since Farrell's (1957), there was a growing demand in developing methodologies to be applied for measurement of efficiency. Early methodologies were deterministic frontier models which attribute all deviations from maximum possible output only to inefficiency. However, recent improvement on early methodologies has made it possible to separately account for factors beyond and within the control of decision makers such that only the latter that causes inefficiency. Developments in production frontier have been an attempt to measure productive efficiency. The production frontier shows the range of maximum possible output levels and identifies the extent to which the farmer lies below or on the frontier.

Productivity shows the ability of the farmer to produce a given quantity of output (it may not be maximum possible output) from the given level of inputs. Hence productivity does not show the relative performance of farmer in producing maximum possible output from the given set of inputs.

According to the neo-classical definition of technical efficiency, a production process is technically efficient if and only if it yields the maximum possible output from a give level of technology and input set. The concept of efficiency can be explained more easily using input or output-oriented approaches. The input -oriented (input overuse approach) measure of efficiency addresses the question "by how much can input quantities be proportionally reduced without changing the output quantities produced?" .The output-oriented approach (output shortfall approach which is the main focus of this study) measure of efficiency addresses the question "by how much can output be increased without increasing the amount of input use by utilizing the given inputs more efficiently?" (Coelli et al., 1998).

5. Methods of Data Analysis

To address the objectives of the research and to analyze the data, both descriptive statics and Econometric methods like stochastic production frontier are used to analyze technical efficiency of farmers in the study area.

Efficiency Estimation

There are two approaches to measure technical efficiency: output-oriented and input-oriented approaches. In the output-oriented approach the interest is by how much output could be expanded from a given level of inputs, hence known as output-shortfall. Whereas in the input-oriented approach the concern is by how much inputs could be proportionately reduced to achieve technically efficient level of production, hence, known as input over-use. In this paper preference has gone to the output-oriented approach, given we are under traditional agricultural settings the concern is rather not that inputs are over-used but output short-fall (Tewodrose(2001) and Zenebe et.al (2005)).

The variation of actual output from the frontier due to inefficiency and random shocks can be captured through stochastic frontier approach .The existence of inefficiency in crop production comes from inefficient use of scarce resources. There exist two main competing methods for analyzing technical efficiency and its principal determinants: the parametric frontier (stochastic frontier approach) and the non-parametric frontier (data envelopment analysis). Non-parametric frontier suffers from the criticism that it takes no account of the possible influence of random shocks like measurement errors and other noises in the data (Coelli, 1995).

The parametric frontier uses econometrics method to estimate the parameters of both stochastic frontier production function and inefficiency effect model. The biggest advantage of stochastic frontier approach is the introduction of stochastic random noises that are beyond the control of the farmers in addition to the inefficiency effects. The disadvantage of this approach is that it imposes explicit restriction on functional forms and distributional assumption for one-sided error term (Battese and Coelli, 1995).

In opposite to the stochastic frontier method, data envelopment analysis is a deterministic frontier, meaning that all deviation from the frontier is attributed to inefficiency only. It is difficult to accept this assumption, given the inherent variability of agricultural production in developing countries due to a lot of exogenous factors like weather shocks, pests, diseases, etc (Coelli and Battese,1995).Furthermore, because of the low level of education of farmers in developing countries, keeping accurate records is not a common practice. Thus, most available data on production are more likely to be subject to measurement errors. As a result of above argument, this study employs a stochastic frontier approach introduced by Aigner et.al (1977), and Meeusen and Van den Broeck (1977).

The stochastic frontier method requires a prior specification of the most widely used functional forms like Cobb-Douglas and Translog. Cobb-Douglas is a special form of the translog production function where the coefficients of the squared and interaction terms of input variables of translog frontier are assumed to be zero. Translog frontier is susceptible to multicollinearity even if it is more flexible form (Thiam et.al, 2001). The Cobb-Douglas production function (in spite of its restrictive properties) is preferred because its coefficients directly represent the output elasticity of inputs and easy for interpretation and estimation than translog frontier (Coelli and Battese, 1998; Seymoun et al., 1998). Hence, in this study preference has gone to Cobb-Douglas frontier due to the above reasons.

Cobb-Douglas stochastic frontier production function

The stochastic frontier production function that assumed Cobb-Douglas form is given as:

$$\ln q = \beta 0 + \beta_1 \ln ld + \beta_2 \ln ox + \beta_3 \ln lb + \beta_4 \ln feqpt + \beta_5 arato + \beta_6 siye + \beta_7 tsenkanet + v_i - u_i \quad \text{......(1)}$$

Where: βi's are parameters denoted the coefficient of inputs to be estimated by maximum likelihood estimation method (MLE). Here they refer to output elasticity for inputs. ln is natural logarithm; q-is the value of output produced by i^{th} farmer; ld- is the total crop area cultivated in 'tsimad'; lb- is the total labor days spent on farm; ox– is the total oxen days used; feqpt-is the total value of farm equipments owned; while arato, siye, and tsenkanet are the name of tabia which take value one if households live in there, zero otherwise. The choice of these convectional inputs is made because these inputs are very important which are commonly used for crop production in the study area.vi - is the random variable assumed to be independently, identically, and normally distributed (iid) N $(0, \sigma^2 v)$; and u_i - is a non-negative random variable assumed to be independently and identically distributed (iid) N $(\mu, \sigma^2 u)$.

Sources of Technical Inefficiency

The level of technical efficiency is estimated as:

$$TEi = \frac{Yi}{Yi^*}$$

$$= \frac{f(xi,\beta i)\exp(\varepsilon i)}{f(xi,\beta i)\exp(vi)}$$

$$= \exp(-ui) \quad \text{...... (3)}$$

Where Yi is the actual output while Y^* is the frontier output or the maximum potential output. To test whether technical inefficiency effect is absent and hence the conventional production function is more appropriate or not than stochastic frontier approach, the study uses the generalized likelihood-ratio test .The results these hypothesis tests are presented in the result and discussion part.

For the inefficiency effect model, the household specific factors are assumed to linearly affect farm technical inefficiency. Given the specification of the stochastic frontier production function, as defined by equations (1), the technical inefficiency effect of the i^{th} farmer is given as:

$$ui=\delta 0+\delta_1 Z_{1i}+\delta_2 Z_{2i}+\delta_3 Z_{3i}+\delta_4 Z_{4i}+\delta_5 Z_{5i}+\delta_6 Z_{6i}+\delta_7 Z_{7i}+\delta 8 Z_{8i}+\delta 9Z9i+\delta 10Z10i+\delta 11Z11i +\delta 12\ Z12i+\delta 13Z13i+\delta 14Z14i+\delta 15Z15i+\delta 16Z16i+\delta 17Z17i+Wi \text{.................................(4)}$$

Where δi's are parameters denoted the coefficient of technical inefficiency effects. Here negative and positive signs of the parameters reveal that they can increase and decrease farmer's technical efficiency, respectively. wi=unobserved random error term; i = number of farmers (1-326 sample respondents). The ML estimates of technical inefficiency effect model given above can be estimated using a software package FRONTIER VERSION 4.1(Coelli, 1996), which is specifically designed for the estimation of efficiency. ui is non-negative random variable, assumed to be independently and identically distributed (i.i.d) with truncated-normal distribution N (μ, σ^2u) (Stevenson, 1980) where μ>0 i.e. u≥ 0 reflects the level of technical efficiency of farmers relative to the frontier. ui= 0 for a farmer whose production lies on the frontier and ui> 0 for a farmer whose production lies below the frontier.

Results and Discussions

Econometric Results

Hypotheses stated in the model specification part and validity of the model which is used for analysis has to be tested before estimating the parameters of the model. One attractive feature of SFA is, it is possible to test various hypotheses , which are not possible in non-parametric model(Obwona,2006;Tedla,2002; Bakhsh,2007;and Thiam et.al.,2001). The following specification tests are performed using generalized likelihood ratio tests: LR[2]=-2[L (H0)-L (H1)], where L (H1) and L (H0) are the values of the log likelihood functions under the alternative and null hypothesis, respectively (Greene, 1980). The ML estimates of all hypothesis tests are found in Appendix part.

The first hypothesis testing is choosing the appropriate functional form for the data from the Cobb-Douglas and Translog frontier. In order to select the most appropriate functional form which adequately represents the data, both Cobb-Douglas and Translog frontiers are estimated using MLE method. The null hypothesis is rejected when the calculated likelihood ratio value (LR) is greater than the critical likelihood ratio value (χC^2). H0: $\beta_8 = \beta_{9=}\ldots= \beta_{29=}0$ is the null hypothesis that identifies the appropriate functional form between Cobb-Douglas and Translog production function that is tested against the alternative hypothesis(all coefficients of the second order and interaction terms in the Translog function are different from zero). As can be seen from table 3.1 below the calculated likelihood ratio value (LR) equals to 33.72 while the critical likelihood ratio value (χC^2) at 22 degree of freedom at upper 1% level of significance equals to 37.6.Since the calculated LR value is less than the critical value of χ^2 at 22 degrees of freedom, not rejecting the null hypothesis at 1% level of significance implies that the Cobb Douglas functional form adequately captures the crop production behavior of farmers in the study area (Kodde and Palm, 1986).

[2] LR denotes log likelihood

The next hypothesis whether the SPF[3] is more appropriate than the convectional production function or whether there is technical inefficiency in the production or not is tested using the null hypothesis, H_0: $\gamma = 0$, where the parameter $\gamma = \sigma^2 u / (\sigma^2 u + \sigma^2 v)$ has mixed chi-square distributions. If this null hypothesis is not rejected, the SPF is equivalent to the convectional production function which is estimated by OLS. In this case, if there is output difference among farmers given equal inputs, this difference is purely due to the difference in random shocks that are outside of the control of the farmer. This hypothesis can be tested using the generalized likelihood ratio test based on the value of log likelihood function under OLS[4] and maximum likelihood estimation (MLE). As can be seen from table 3.1 below the calculated likelihood ratio value (LR) equals to 78.85 while the critical likelihood ratio value (χC^2) at 1 degree of freedom with upper 1% level of significance equals to 6.63.Since the calculated LR value is greater than the critical value of χ^2 at 1 degrees of freedom, rejecting the null hypothesis implies that SPF is more appropriate than convectional production function or there is significant technical inefficiency variation among the smallholder farmers.

The third hypothesis is that the explanatory variables in technical inefficiency effect model are simultaneously equal to zero, H_o: $\delta_0 = \delta_1 = \delta_2 \ldots = \delta_{17} = 0$. To test this hypothesis log- likelihood ratio is calculated using the value of the log likelihood function under the Cobb-Douglas stochastic frontier model (a model without explanatory variables of inefficiency effect model, H_0) and the full frontier model (a model with all explanatory variables of inefficiency effect model, H_1). The calculated value of LR equals to 30.86 while the critical likelihood ratio (χC^2) of upper 5 percent level of significance at 17 degree of freedom equals to 27.6.Since the calculated likelihood ratio , LR , value is greater than the critical value of LR , $\chi C2$, at 17 degree of freedom with upper 5 % level of significance, the null hypothesis that determinant variables in the inefficiency effect model are simultaneously equal to zero is rejected at 5 % level of significance. Therefore, the explanatory variables associated with

[3] Stochastic Production Frontier
[4] Ordinary Least Square

inefficiency effect model are jointly different from zero. Hence these variables jointly explain inefficiency differences among the farmers.

The fourth hypothesis testing is for about the distributional assumption of the one sided error term. Given Cobb-Douglas stochastic frontier production function best fits the data; the researcher tests hypothesis whether the technical efficiency level is better estimated using a half- normal (μ=0) or a truncated-normal distributional assumption of U_i (μ>0) using FRONTIER VERSION 4.1.This software is designed only for half - normal and truncated-normal distributional assumption for inefficiency effect. As can be seen from table 3.1 below the calculated likelihood ratio value (LR) equals to 30.11 while the critical likelihood ratio value (χC^2) at 1 degree of freedom with upper 1% level of significance equals to 6.63.Since the calculated LR value is greater than the critical value of χ^2 at 1 degrees of freedom, rejecting the null hypothesis implies that truncated-normal distributional assumption of one sided error term is more appropriate for the farmers in the study area than half-normal. Again the ratios of the standard error of *u* to that of *v*, λ (3.88) exceeded one in value and are statistically different from zero at the 1 % level of significance. The values of λ and the fact that it is significantly different from zero implies the good fit and the correctness of the specified truncated normal distributional assumption of the one sided error term.

The last hypothesis testing is the test for returns to scale. The results of the estimation made under both model specifications, constant and variable return to scale, show that the value of log-likelihood functions equal to –448.93 and –413.60, respectively. Thus, the log likelihood-ratio test is calculated to be 70.66 and when this value is compared to the critical value of χ^2 at 4 degrees of freedom with 1% level of significance equals to 13.28, the null hypothesis that the Cobb-Douglas production function is characterized by constant return to scale is strongly rejected. The sum of the partial elasticity of all inputs equals to 1.73.This means an increase in all inputs at the sample mean by one percent will increase crop production in the study area by 1.73 %. This reveals that the production function is characterized by increasing returns to scale. This shows that the elasticity of mean value of output is estimated to be an increasing function of land, labor, ox, and farm equipment. This is due to the reason that as the farmers get richer so can invest in more inputs and use it for high valued crops.

Stochastic Frontier Production Function Results

As already stated above, the present study employs one stage maximum likelihood estimation procedure to simultaneously estimate the parameters of both stochastic frontier production function and inefficiency effect model. The result reveals that all input variables, except labor, have significant effect on crop production in the study area. Contrary to the prior expectation, labor with positive sign turned out to be insignificant.

For the case of inefficiency effect model, all determinant variables except sex of household head, farm size, access to irrigation, and member to association are significantly responsible for technical efficiency variation among the farmers. The sign of coefficients of both input variables and inefficiency effects have been as prior expectation except sex of household head. Education of household head, literate members of household head, family size, participation in share cropping, credit access, crop diversification, and land fertility are found to enhance farmers' technical efficiency. In contrast, households' age, dependency ratio, livestock size, off-farm activities are found to increase technical inefficiency.

Given the Cobb-Douglas functional form used, stochastic frontier approach implemented, truncated normal distribution of the inefficient effect assumed, the mean technical efficiency is estimated to be 60.38% with minimum of 0.13% and maximum of 88.64%. This indicates that average technical efficiency of farmers in the study area is a little bit above the mid-way to the frontier. The estimated values of gamma (γ) of both functional forms (0.9378 in the case of Cobb-Douglas and 0.9070 in the case of Translog frontier) reveal the fact that farmers in the study area are technically inefficient and there is significant efficiency variation among the farmers. This again reveals the fact that most farmers in the study area are using their existing resources inefficiently.

Using the values of the actual output observed and the predicted technical efficiency scores of each sample farmer(for the case of C-D SFPF[5]), the potential output is estimated for each farmer in Birr. The mean value of the actual output and the mean value of the potential output are 1383.549 Birr and 2291.40 Birr, respectively. 93.78% of this output variation is due to variation in technical efficiency among the farmers while the remaining 6.22 % is due to statistical noises which are not under the control of the farmers. This shows that there is wider room for rising crop production in the study area by improving the efficiency of inefficient farmers without undertaking additional investment on modern agricultural technology, given the fact that technical efficiency of farmers is directly related to the overall productivity of the agricultural sector.

As far as the frequency distribution of technical efficiency estimates of households is concerned, nearly 36.2% of the farmers having efficiency score below the mean 0.60; the remaining 54.6% of the farmers have efficiency scores ranging from 0.60 to 0.80; and only 9.2% of the respondent farmers having efficiency score above 0.80. The distribution of the technical efficiency scores clearly shows that it is skewed heavily in the range of 0.60 to 0.80, representing more than half of the sample farmers. The wide variation in technical efficiency is an indication that most of the farmers in the study area are still using their resources inefficiently in the production process and there still exists opportunities for rising their crop production by improving their current level of technical efficiency.

Using one stage estimation procedure, the parameters of both stochastic production frontier and technical inefficiency models were estimated as follow.

[5] Cobb-Douglas Stochastic Frontier Production Function

Maximum-likelihood estimates of truncated normal stochastic frontier production function results

Variable names	Coefficient	standard-error	t-ratio
Input variables			
Constant	4.38	0.282	15.52***
lnld (tsimad)	0.36	0.141	2.56***
lnlb(man power)	0.21	0.166	1.26
lnox(oxen days)	1.00	0.209	4.779***
lnfeqpt(Birr)	0.16	0.046	3.45***
Arato	0.83	0.186	4.48***
Siye	-0.12	0.207	-0.596
Tsenkanet	1.12	0.170	6.64***
Inefficiency variables			
Constant	-9.23	2.91	-3.17***
Household gender	0.63	0.771	0.82
Age of household heads	-2.12	0.877	-2.42**
Age square	0.14	0.077	1.81*
Household education	-0.002	0.0008	-2.85***
Family size	-1.37	0.814	-1.69*
Dependency ratio	0.50	0.171	2.94***
literate members	-0.855	0.311	-2.74***
Livestock size	0.29	0.101	2.91***
Access to credit	-0.0001	0.00006	-2.11**
Farm size	-0.56	0.846	-0.66
Farm size square	0.78	0.237	3.30***
Crop diversification	-0.07	0.016	-4.39***
Participation in irrigation	-0.50	0.755	-0.66
Share cropping	-1.35	0.662	-2.04**
Off-farm activities	2.44	0.753	3.24***
Land fertility	-2.95	0.780	-3.78***
Members to association	-0.11	0.160	-0.69
σ^2	5.23	1.113	4.70***
γ	0.9378	0.018	49.92***
λ	3.88		
LL	-398.13		
Mean TE	0.6038		

Source: Own computation from rural Tigray micro finance survey (2009)

***= significant at 1 %; **=significant at 5 %;*=significant at 10 %

Variables that are considered as principal determinants of technical efficiency can be categorized into three such as demographic characteristics (sex, age, education of household head, number of literate family members, family size, dependency ratio), resource factors (livestock size, farm size, and land fertility) and institutional and other associated factors (access to credit, participation in irrigation, members to association, off-farm activities, crop diversification etc). Households' sex ,access to irrigation, farm size ,and members to association have not been found to explain the argument why some farmers are technically more efficient while others are technically less efficient, although their signs are as expected except sex. Greater attention has to be given during interpretation of the signs of coefficients of technical inefficient effect. Positive sign of the coefficient of one variable shows the negative effect of that variable on technical efficiency. The opposite is true for negative sign of the coefficient of the variable. This is because the dependant variable is technical inefficiency not technical efficiency of the farmers.

. Demographic characteristics

Age of Household Head: Age and age square have been found to be significant variables in explaining the variation in technical efficiency among farmers .Age of the head of household, which is considered as a proxy of farmers' experience in farming, is hypothesized to have positive effect on efficiency. The result also supports the hypothesis that age and age square have positive and negative significant effect (at 5% and 10 % level of significance, respectively) on inefficiency. This is because as age increases farming experiences increases so that efficiency increases. But after certain age interval it will have negative effect on efficiency because of older farmers are thought to be more conservative in implementing modern technologies. This means that age and efficiency have inverted u-shaped relationship i.e. efficiency increases with age up to some point and then decreases with rise in age. Hence, middle aged farmers are more efficient than old aged and younger farmers. Since farming like any other professions needs accumulated knowledge, skill and physical capability, age of the farmers is decisive in determining efficiency. The knowledge, the skills as well as the physical capability of farmers is likely to increase as age increases. However this tends to decrease after a certain age level. Older farmers will have less physical capacity to undertake their farming activities efficiently. This finding is consistent with work of Chirwa (2007).

Education of household head: It is hypothesized that educated household head would be able to have higher technical efficiency from the given level of inputs than their illiterate counterpart. The result also supports the hypothesis that education of household head has been found to be significant variable (at 1% level of significance) to enhance efficiency of farmers. This is because education can increase their information acquisition and adjustment abilities, thereby- increasing their decision making capacity. In addition to this it will help them to adopt modern agricultural technologies and be able to produce higher output using the existing recourses more efficiently.

Family size: The number of persons living in the household is hypothesized to determine efficiency positively. The result shows that family size has positive and significant effect (at 10% level of significance) on efficiency. This means that households with large family size would manage crop plots on time than their counterparts. This is because at the time of peak seasons, there is shortage of labor. This is possible since more labor can be deployed during peak season in order to timely undertake the necessary farming activities like ploughing, weeding and harvesting that raise efficiency.

Literate members of household heads: Number of literate of family members is hypothesized to have positive effect on technical efficiency. The result also shows that literacy of family members is found to be significant variable (at 1% level of significance) for determination of farmers' efficiency. It has positive and significant effect on efficiency. As the education level of family members' increase it is expected to increase their information acquisition and adjustment abilities, thereby- increasing their decision making capacity by which their attitude will be shaped on in adopting modern agricultural technologies that increase farmer’s efficiency. Therefore, households with more literate family members are expected to have better efficiency than their counterparts.

Dependency Ratio: Household with high dependency ratio is hypothesized to be less efficient than his counter parts. The result also shows that dependency ratio has negative and significant effect (at 1% level of significance) on efficiency. This reveals those households with high dependency ratio is more likely to be less efficient than those with low dependency ratio. This is due to the reason that as the number of dependant family members (economically inactive) increase the household would have to allocate more financial resources to their health, education and other expenses so that less resources might remain for production purposes (may not be able to use improved inputs). In other words since family size is controlled higher dependency ratio means less productive workers which results more consumption and less production. As a result of this households couldn't afford to use improved agricultural technologies like fertilizers, improved seed varieties etc due to liquidity constraints.

Resource Endowment Factors

Livestock size: The result shows that the value of livestock owned is found to be negative and significant (at 1% level of significance) in determining efficiency variation among the farmers. It is obvious that the crop husbandry is highly supplemented and complemented by the animal husbandry. It has systematic effect on efficiency i.e. the farmer who possesses more number of livestock will have more money to purchase agricultural inputs, and again has the chance to get oxen for draught power. Since all types of animals, poultry and beehive production are considered in this study, livestock competitive effect has dominated its supplementary effect. This might be due to the reason that farmers who held more livestock may tend to give their due attention to livestock production and hence crop production may be lagged behind it.

Land fertility: It is hypothesized that farmers with fertile lands are more efficient than their counterparts. The result also supports the hypothesis that land fertility is found to have positive and significant effect (at 5% level of significance) on efficiency. This is because fertile lands are expected to increase productivity. A farmer endowed with fertile land will be more technically efficient than infertile lands. This is in line with other empirical findings like Chirwa (2007).

Institutional and other associated Factors

Access to credit: It is hypothesized that households who have got credit access is more efficient than their counter parts. The result shows that credit access is found to have positive and significant effect (at 5% level of significance) on farmers' technical efficiency in production. This implies that credit availability shifts the cash constraint outwards and thus enables farmers to make timely purchases of inputs that they cannot afford otherwise from their own resources and enhances the use of agricultural inputs that leads to higher efficiency**.** This result is consistent with other empirical works like Kinde (2005) and Gebrehawaria (2008), although for irrigated plots only.

Off-farm activity: The result reveals that off-farm activity has negative and significant effect (at 1% level of significance) on farmers' efficiency. Of course being involved in off/non- farm activities may have a systematic effect on the technical efficiency of farmers. This is because farmers may allocate more of their time to off/non- farm activities and thus may lag in agricultural activities. On the other hand, incomes from off/ non-farm activities may be used as extra cash to buy agricultural inputs and can also improve risk management capacity of farmers. However, the result shows that agricultural lag effect of off-farm activity has dominated its income effect. This result is consistent with other empirical works like Obwona (2006), Kibaara (2005), and Chirwa(2007) .

Crop diversification: It is hypothesized that a farmer engaged in crop diversification is more efficient than his/her counterpart. Beside for commercialization, it is used as risk minimization during crop failure. The result also shows that crop diversification has positive and significant effect on farmers' efficiency (at 1% level of significance). This is due to the reason that farmer engaged in crop diversification is more efficient in allocating their resources like labor and land than his/her counterpart.

Share cropping: It is hypothesized that farmers tend to be less efficient in managing those lands that are owned or rented in than sharecropped. Supporting the hypothesis, the result shows that sharecropping is found to have positive and significant effect (at 5% level of significance) on efficiency. This might be due to the reason that sharecropping may motivate the tenants to work hard to meet their contractual obligations. They may do so because outputs that will be obtained from sharecropped in lands are eventually shared between the land owner and the tenant. Therefore, farmers are expected to give priority to their share cropped land than to their own or hired lands. In other words, farmers who are managing either their own lands or hired lands are less efficient than those farmers who are managing sharecropped lands.This result is in line with the result of Bakhsh (2007) and Chirwa(2008).

6. Conclusion and Recommendation

Conclusion

The study uses both descriptive and econometric methods in order to analyze the data. Hypotheses tests confirm the adequacy of Cobb-Douglas frontier over Translog frontier for the data; the appropriateness of using stochastic frontier production function over convectional production function; the joint statistical significance of inefficiency effects; the appropriateness of using truncated-normal distribution assumption for one sided error term; and the increasing returns to scale nature of the stochastic frontier production function.

Using one step maximum likelihood estimation procedure, the parameters of both Cobb-Douglas stochastic frontier production function and technical inefficiency effect model are estimated simultaneously. Hence, results show that except labor all input variables have significant effect on crop production in the study area and number of oxen owned has the highest elasticity, then land, followed by labor, and value of farm equipments with value of 1, 0.36, 0.21, and 0.16, respectively. This is an indicative of the importance of traditional inputs in subsistence agriculture. Results reveal that the use of more labor does not have significant contribution to crop production due to the existence of surplus labor in the study area. This implies that enhanced access and better use of conventional inputs like ox and land could lead to higher crop production in the study area.

The empirical findings show that the predicted efficiencies vary widely among the sample farmers with a mean technical efficiency value of 0.6038. This indicates that it is little bit above the mid way to the frontier. The significant value of gamma, 0.9378, reveals the fact that a high level of technical inefficiency exists among the sampled farmers. The wide variation in technical efficiency is an indication that most of the farmers are still using their resources inefficiently in the production process and there still exists opportunities for increasing their crop production by improving their current level of technical efficiency. Hence, production in the study area can be increased by 39.62% at the existing level of inputs and current technology by operating at full technical efficient level. This is because the benefits of introduction of modern technologies cannot be realized in the presence of higher technical inefficiency.

In most of the farmers, the variation of actual output from the frontier has been arisen so much from differences in the farmers' ability to use the best practices/due to inefficiency. Since much of the inefficiency in crop production is attributed to technical inefficiency, improvement in technical efficiency of farmers needs a priority attention as it provides a significant source for productivity growth . This reveals the wider room for increasing crop production and productivity by improving the efficiency of farmers at the existing technology. This inefficiency, however, can be improved if principal factors that determine efficiency are identified.

The estimated SPF model together with the inefficiency parameters shows that all determinants except household heads' sex, farm size, participation in irrigation, and member to association have significant effect on efficiency. The sign of coefficients of determinants have been as the expected, except sex of household heads. Household heads' education, family literacy, family size, participation in share cropping, credit access, crop diversification, and land fertility are found to enhance farmers' technical efficiency. In contrast, households' age, dependency ratio, livestock size, and off-farm activity are found to increase inefficiency.

Results also reveal that Tsenkanite farmers exhibit relatively higher efficiency scores followed by Arato, Siye and Rubafeleg farmers. The better efficiency score in Tsenkanite may be due to the existence of on-going interventions in the tabia, since it is one of the millennium villages. Comparatively, Arato has better market access and some irrigation scheme that help them farmers to render better performance. The low efficiency score of households in Rubafeleg and Siye may be due to past and frequent occurrence of shocks in these tabias which have adverse impact on farmers' efficiency by reducing their productivity and shifting their resources towards mitigation of losses and reconstruction efforts.

. Policy Recommendation

The attention of policy makers to mitigate the existing level of food deficiency and poverty by improving agricultural productivity should not stick only to the introduction and dissemination of modern agricultural technologies but they should also give due attention towards improving the existing level of inefficiency of farmers. The argument here is that improvements in the agricultural productivity in the use of modern technologies are expensive, require relatively longer time to achieve and farmers have serious financial problems to afford them. Moreover, the result of increment of productivity and production of agricultural sector by using improved technologies will be high if it is coupled with the improvement of the existing level of inefficiency of farmers. Since the existence of higher inefficiency and the principal factors that are responsible for the efficiency variation among the farmers have important policy implications so as to mitigate the existing level of inefficiency of farmers in the study area, the following policy recommendations have been drawn based on the results of the study.

The positive and higher elasticity of convectional inputs like ox, land, and farm equipments indicate the importance of traditional inputs in subsistence agriculture. This implies that enhanced access and better use of these conventional inputs could lead to higher crop production in the study area. Therefore, policy makers should made further efforts in strengthening financial institutions like micro finance and other arrangements that can relax farmers' liquidity constraints and help them to afford these traditional inputs.

It is observed that, in the study area, both education of household heads and family members is positively related to technical efficiency. Hence, any agricultural policy that would educate people through proper agricultural extension services would definitely lead to increase efficiency of the farmers there by agricultural productivity. Therefore, it is possible to recommend that the regional government should have a prime responsibility to keep on provision of education in these areas and others so that farmers can use the available inputs more efficiently under the existing technology.

Results indicate that land fertility is found to have positive and significant effect on efficiency. The policy implication is that improving and maintaining fertility status of land by applying improved land management practices would increase efficiency of farmers there by crop production. The result reveals that there is land shortage in the study area as a result of high population growth. Hence, early interventions are called for intensive and efficient use of land farming practice.

In conclusion, the existence of higher technical inefficiency in the study area indicates that integrated development efforts that will improve the existing level of input use and policy measures that will decrease the existing level of inefficiency of farmers will have great importance in improving the living standard of farmers at large. Given limited resources, it would be wise and obviously better for the government and other concerned parties (like NGOs) participating in developmental activities to encourage development endeavors towards improving the level of efficiency of the farmers in the study area to be cost effective as compared to introduction of new technologies. However, the continuation of technology development and its dissemination is indispensable and both ways of increasing productivity have to be followed, although priority should be given to the improvement of efficiency of inefficient farmers.

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