INTERNATIONAL

RESEARCHERS

THE EFFECT OF AGRICULTURAL EXTENSION PROGRAM ON TECHNICAL EFFICIENCY OF RURAL FARM HOUSEHOLDS EVIDENCE FROM NORTHERN ETHIOPIA: STOCHASTIC FRONTIER APPROACH

Mohammed Adem and Kidanemariam Gebregziabher

Volume No.3 Issue No.3 September 2014

www.iresearcher.org

ISSN 227-7471

THE INTERNATIONAL RESEARCH JOURNAL "INTERNATIONAL RESEACHERS"

www.iresearcher.org

INTERNATIONAL RESEARCHERS is peer-reviewed, supported by rigorous processes of criterion-referenced article ranking and qualitative commentary, ensuring that only intellectual work of the greatest substance and highest significance is published.

INTERNATIONAL RESEARCHERS is indexed in wellknown indexing diectories

with ICV value 5.90

and moniter by

THE EFFECT OF AGRICULTURAL EXTENSION PROGRAM ON TECHNICAL EFFICIENCY OF RURAL FARM HOUSEHOLDS EVIDENCE FROM NORTHERN ETHIOPIA: STOCHASTIC FRONTIER APPROACH

Mohammed Adem (MSc) [1], **Kidanemariam Gebregziabher (PhD)** [2]

[1, 2] Mekelle University, Department of Economics

(**ETHIOPIA)**

ademoha@gmail.com[1], kg9676@gmail.com[2]

ABSTRACT

Agricultural is the backbone of Ethiopian economy, therefore, increasing the productivity of this sector leads to an increase in income of rural households as well as food security. The productivity of farmers can be raised by either adoption of improved agricultural technologies or improvement in efficiency of farmers or both. Nevertheless, with the low rate of adoption of improved agricultural technologies by farmers in Ethiopia improving efficiency becomes the best option for productivity enhancement in short run. Therefore, the main concerns of the study is to measure and compare the current level of technical efficiency of extension participant and non-participant households who produced crop and; to examine the sources of technical inefficiency of these farmers. The study used the data collected by MU-IUC socio-economic research project during 2009/2010, which contains sample of 390 participants and 344 non participants, total of 734 respondents from Atsebi-wemberta, Wukro, Saharti - Samre and Tanqua-Abergle woreda's.

In order to measure the technical efficiency of farm households' parametric techniques of frontier models was used and the parameters of the stochastic frontier production function, Cobb-Douglas type, were estimated using the maximum likelihood method. The results indicated that efficiency of participant farmers (57%) were greater than the non-participant ones (53%) which implying that there exists significant potential to improve crop production for the two groups. The study also identifies that farm household efficiency varied from 7 % to 90 % widely across households. Finally, the study recommends that through creation awareness for farmers to participate in the extension service and reducing the sources of technical inefficiency by addressing some important policy variables that negatively and positively influenced farmers' levels of efficiency; it is possible to increase productivity of farmers in the study area.

Key words*:* Technical Efficiency, Extension Service, Participant and Non-Participant

1. INTRODUCTION

Ethiopia is the second most populous country in sub-Saharan Africa, with an estimated population of 78 million. Agriculture is the largest sector of the economy which contributing about 46 % of the country's GDP, over 90% of exports and employing over 83% of the population (US. government initiative, 2010). However , like in many other developing countries, agriculture stays at poor performance which is explained by its inability to feed the growing population, lack of structural transformation magnified by agriculture's continued dominance in Gross Domestic Product (GDP), and the limited role that agriculture has played in serving as an engine of growth in economic development (Alemu et al. ,2009).

In order to meet the food needs of its rapidly growing population, the country needs to double its cereal production by 2025. The long-term agricultural production and productivity for Ethiopia over the last four decades indicate that the growth rate in crop yields (1.4 percent per year during 1960-2001 periods) lags behind population growth (2.5 percent per year).In addition, variability in yields is becoming more pronounced, making farmers' decisions regarding crop choice and input use more complicated. The trends in agricultural yields and input use also indicate slow growth rate of cereal yields, in spite of substantial increases in the use of modern agricultural input (Geremew, 2005). The main reasons for the existing structural food insecurity in the country are the low level of technological development, which acts as the principal barrier to the efficient utilization of the country's natural resources, low yield due to low adoption of improved agricultural technologies and low productive efficiency. The relative efficiency of farmers is also very important because it is a factor for aggregate productivity growth and an influence on income distribution (Endris, 2010).

As Schultz (1964), hypothesized that farm families in developing countries were “efficient but poor”,[1] and thus that “there are comparatively few significant inefficiencies in the allocation of the factors of production in traditional agriculture”. This hypothesis led policy makers to believe that; improvement could not be achieved since the farmers adhere to their existing outdated production technologies. Consequently, this has resulted in policies emphasizing in generating new and more productive technologies. Introduction of new technology requires intensive inputs of managerial skill and information, good education and extension services, and adequate infrastructures.

Agricultural extension work in Ethiopia began in 1931 with the establishment of the Ambo Agricultural School that is one of the oldest agricultural institutions in Ethiopia and the first agricultural high school offering general education with major emphasis on agriculture. However, real agricultural extension work began in the early 1950 following the establishment of the Imperial Ethiopian College of Agriculture and Mechanical Arts (IECAMA, now Alemaya University) with the assistance of the United States of America under the Point Four Programmes. The academic programme of the College was modeled on the Land Grant College system with three fundamental but related responsibilities; training high-level work force; promoting agricultural research and disseminating appropriate technologies. The role played by the IECAMA in developing the agricultural extension system is considerable. In fact, when the College was founded and it was given the mandate to develop and deliver a national programme in agricultural extension. During the next few years, the number of extension agents increased considerably and they were stationed at posts all around the country (Belay, 2005).

However, in the mid-1970s socialism was introduced as the political system of the country. Therefore the MPPI of the imperial regime was renamed MPPII in 1981 after the renewal of the World Bank’s commitment to finance the project. In 1984, the Peasant Agricultural Development Extension Programme (PADEP) replaced the MPP. It differed from the MPP projects in that it aimed to develop and disseminate appropriate technologies at the zonal level, using a training-and-visit approach. PADEP gave way to a new agricultural extension programme known as the Participatory, Demonstration and Training Extension System (PADETES) in 1994/95. The main difference between PADEP and PADETES is that PADETES merges the training-and-visit approaches of PADEP with the technology diffusion system (Alemu, 2005).

Since 1991, however, the government became determined to address the development issues, namely under guided or directed by the strategy of agricultural development led industrialization (ADLI).PASDEP was proposed as a remedy to rectify drawbacks observed during the implementation of packages programs. Public extension service has been as a main means of achieving these development initiatives and strategies. It emphasized better research extension linkage encouraged aggressive work in technology transfer to small holders, and made effort to strength the capacity of the extension system to disseminate research proven pre and post harvest technologies mainly on food crops (MoFED, 2006).

According to Byerlee (2007), agricultural technology is viewed as a means through which agricultural efficiency, productivity and production improvement can be made in the fight against hunger and poverty. In order to transforming Ethiopian agriculture from its current subsistence orientation into market orientated production system, government designed various agricultural development strategies. The agricultural extension service is one of the institutional support services that have a central role to play in the transformation process. The government and non-governmental organizations have consistently promoted use modern agricultural inputs as a yield augmenting technology. Despite this promotion, adoption modern agricultural input rates remain very low which leads to low productivity.

To shade a light about the inefficiency levels of farm producers, first the concept of efficiency needs to be clarified. Usually, efficiency is used as a synonym for yield or productivity in the literature. However, there is a wide discrepancy between these concepts and efficiency. Efficiency can be defined as ability to produce maximum amount of output by employing minimum amount of inputs while yield and productivity are partial efficiency measures (Tung Vu, 2010). Partial efficiency measures do not give any information about the ability of producers to utilize inputs. However, efficiency structure of farm production remains to be an unexplored topic. It is apparent that appropriate

[1] Schultz, who won the 1979 Nobel Economics Prize, makes the very important point that farmers in low income countries are rational and make effective use of their resources. Traditional farmers, given a long enough period of time to learn their production processes, will identify their respective optimal input and output bundles. So, they are poor because their resources are very limited and because the knowledge is not available that would permit them to produce the same output with fewer resources or a larger output from the same resources. Peasant (small) farmers in traditional agricultural settings are reasonably efficient in allocating their resources.

policies to increase the efficiency of farmers cannot be devised without proper information about the current efficiency level of the farms and effects of different factors on efficiency.

Different studies have been carried out in different countries (including Ethiopia) to measure technical efficiency and productivity of rural farm household and these studies have revealed different results. Since these studies only highlights what appears to be important in general or on average. Therefore, a country specific analysis is important to identify farm specific efficiency level of farm household. Therefore, the main objectives of this study are; to measure the effect of agricultural extension on technical efficiency of rural farm households, to examine the sources of technical inefficiency of farmers in rural area.

1. ANALYTICAL FRAMEWORK

In order to measure the technical efficiency of farm households parametric technique was used. There are two common approaches in the literature for estimating technical efficiency. One approach is based on non-parametric, non-stochastic, linear programming (Data Envelopment Analysis). However, this suffers from the criticism that it takes no account of the possible influence of measurement error and other noise in the data (Coelli, 1995). The second approach uses econometrics to estimate a stochastic frontier function, and to estimate the inefficiency component of the error term. The disadvantage of this approach is that it imposes an explicit and possibly restrictive functional form on the technology. However, this approach is chosen here because it considers both random shocks and inefficiencies that is the focus of this paper. The stochastic frontier model (SFM) independently proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977) is applied in the analysis of data.

2.1 THE STOCHASTIC FRONTIER PRODUCTION MODEL

We have adopted the stochastic frontier production function since agricultural crop production exhibits random shocks and there is a need to separate the influence of stochastic variables (random shocks and measurement errors) from resulting estimates of technical inefficiency. Several studies have used the stochastic production function approach to determine the level of technical efficiency (Arega ,2002; Mulat and Bekele ,2003; Gebreegziabher et al.,2004; Arega et al. ,2005; Gebregziabher et al. ,2008 ; Endris,2010).The stochastic frontier production function model for estimating farm level technical efficiency is specified as
:

$$Yi = f(X_i; \beta) \exp(\varepsilon_i) \qquad i = 1, 2 \ldots n \qquad (1)$$

Where Yi is output, Xi denotes the actual input vector, β is vector of production function parameter to be estimated and ε is the error term that is composed of two elements. That is:

$$\varepsilon = V_i - U_i \qquad (2)$$

Where V_i is the symmetric disturbances assumed to be identically, independently and normally distributed as N (0, σ^2_v) given the stochastic structure of the frontier. The second component U_i is one-sided error term that is independent of V_i and is half normally distributed as $N^+(0, \sigma^2_u)$, allowing actual production to fall below the frontier but without attributing all short fall in output from the frontier as inefficiency. The stochastic production frontier at a technically efficient household would represent the maximum attainable output □□Y_i*□ as:

$$Y_i^* = f(X_i; \beta) \exp(V_i) \qquad (3)$$

The farm-specific technical efficiency is defined in terms of observed output (Y_i) to the corresponding frontier output (Y_i*) using the available technology is given by:

$$TE_i = Y_i/Y_i^* = \frac{E(Y_i | u_i, X_i)}{E(Y_i | u_i = 0, X_i)} = E[\exp(-Ui)/\varepsilon i] \qquad (4)$$

So, technical efficiency takes value on the interval, [0, 1], where 1 indicates a fully efficient farm household.

The estimation of the stochastic production frontier function may be viewed as a variance decomposition model, which can be expressed as:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \qquad (5)$$

$\gamma = \frac{\sigma_u^2}{\sigma^2}$ Where, $0 \leq \gamma \leq 1$ (6)

Different forms of production function are used in the empirical studies, depending on the nature of the data on hand. Therefore, the selection of functional form is vital issue in the stochastic frontier production. In a number of studies, Cobb-Douglas production function has been used to examine farm efficiency notwithstanding its well known limitations (Battese ,1992 ;Bravo-Ureta ,1993;Thaim,et al. 2001).

The Cobb-Douglas functional form is used even with its well known limitations because it is uncomplicated to estimate and mathematically manipulate. Kopp and Smith, 1980 indicated that this functional form has a distinct but rather has small impact on estimated efficiency. Ahmed and Bravo-Ureta (1996), rejected the Cobb-Douglas functional form and favored the translog form and but concluded that technical efficiency measure do not affected by the selection of the functional form. The flexible functional form like transcendental logarithmic (translog) functional form does not entail restrictions of fixed rate of technical substitutions (RTS) value and an elasticity of substitution equivalent to one as in the case of Cobb-Douglas form upon the production function. Therefore, the translog production functional form is preferred over the Cobb-Douglas functional form. It is noted that the Cobb-Douglas production is nested with in translog form if all the square and interaction terms in the translog turnout to be equal to zero.

In order to select the best specification for the production function (Cobb-Douglas or translog) for the given data set, likelihood ratio test is conducted for the parameters of the stochastic production frontier model.

$$LR=-2\{\ln(H_0)/(LH_1)\} \quad (7)$$

$$LR=-2\{\ln(H_0)-(LH_1)\} \quad (8)$$

Where,

$L(H_0)$ is value of the likelihood function of the Cobb-Douglas stochastic production frontier model, in which the parameter restrictions specified by the null hypothesis, $H_0 = b_i = 0$, (i.e. the coefficient on the squared and interaction terms of input variables are zero) are imposed;

$L(H_1)$ is the value of the likelihood function for the full translog stochastic production frontier model (where the coefficients of the squared and interaction terms of input variables are not zero). If the null hypothesis is true, then "LR" has approximately a chi-square (or mixed chi-square) distribution with degrees of freedom equal to the difference between the number of parameters estimated under H_1 and H_0, respectively. Based on the test statistics production function is selected (See result & discussion for this).

Therefore, a Cobb-Douglas production function for cross sectional data set has been specified as follows:

$$ln(Y_i) = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + V_i\_U_i \quad (9)$$

Where: Y_i is the dependent variable in the production function showing crop yield value for i-th farm household.

ln Represents natural logarithm of crop yield and input variable

$\beta_0, \beta_1, \ldots, \beta_7$, are the unknown parameters to be estimated.

X_1 = the size of cultivated land measured in terms of tsimdi[2] of each household.

X_2 = the total amount of seed value used in the production process (in Birr)

X_3 = the total labor used that means both family and hired labor in the production (man-days

X_4= the total amount of fertilizer value applied on the cultivated land of the household (in Birr)

X_5 = the number of total oxen used (oxen-days)

X_6= the amount of manure used in the production process (in Kg)

X_7= the value of agricultural equipment the farm household (in Birr)

V_i = a disturbance term with normal distribution properties as explained above

U_i = farm specific inefficiency error term

According to Chirwa E.W. (2007), two methodological approaches Suggested for analyzing the sources of technical inefficiency based on stochastic production functions. The first approach is the two-stage estimation procedure in which first the stochastic production function is estimated, from which efficiency scores are derived. In the second stage, the derived efficiency scores are regressed on explanatory variables using ordinary least square methods or Tobit regression. This approach has been criticized on grounds that the firm's knowledge of its level of technical inefficiency affects its input choices; hence, inefficiency may be dependent on the explanatory variables. The second approach advocates a one stage simultaneous estimation approach as in Battese and Coelli (1995), in which the

[2] One tsimad= 0.25 heactar

inefficiency effects are expressed as an explicit function of a vector of farm-specific variables. The technical inefficiency effects are expressed as:

$$u_i=\delta_i z_i+\varepsilon_i \qquad (10)$$

Where for farm household i, z is a vector of observable explanatory variables and δ is a vector of unknown parameters. Thus, the parameters of the frontier production function are simultaneously estimated with those of an inefficiency model, in which the technical inefficiency effects are specified as a function of other variables. The one-stage simultaneous approach is also implemented in FRONTIER 4.1 version and in addition to the basic parameters; the program provides coefficients for the technical inefficiency model. Several factors, including socioeconomic and demographic factors, plot-level characteristics, environmental factors, and non-physical factors are likely to affect the efficiency of smallholder farmers. However, the following explanatory variables are used in this regression analysis.

Z_1 = plot distance
Z_2 = access for wage income Dummy: 1 if the farmer had access to wage income
Z_3 = improved seed use Dummy: 1 if the farmer uses improved seeds
Z_4 = inorganic fertilizer use Dummy: 1 if the farmer used fertilizer on the plot
Z_5 = number of crops produced
Z_6= dependency ratio
Z_7 = plot size
δ_i= Regression parameters
ε_i= Error term

2. STUDY AREA, DATA AND DESCRIPTIVE STATISTICS

3.1. DESCRIPTION OF THE STUDY AREA

Ethiopian is divided into nine regional states and two-city administration. Tigray Regional State is the one among the nine regional states that is located in the northernmost of Ethiopia. The state located at 12^o15-4^o57 longitude and 36^o27- 39^o59 latitude. The State of Tigrai shares common borders with Eritrea in the north, the State of Afar in the east, the State of Amhara in the south, and the Republic of the Sudan in the west. Excluding Mekelle town, the state capital, there are five administrative zones: comprising a total of 47 weredas (districts) and 673 tabias (sub-districts) http://www.tigraionline.com/tigraistate.htm. According to Central Statistics Authority of 2007, Census the region has an estimated total population of 4,314,456, of whom 2,124,853 are men and 2,189,603 women; urban inhabitants number 842,723 or 19.53% of the total population. With an estimated area of 50,078.64 square kilometers, this region has an estimated density of 86.15 people per square kilometer.

This study conducted in the Geba catchment with in Tigray region. The catchment, located in the eastern, southern and central zones of Tigray (Northern Ethiopia), covers about 5180 km^2 and has a semi-arid climatic condition with erratic and torrential rainfall that often lasts for 2- 3 months, end June to beginning of September. The short rainy season coupled with high rainfall variability between seasons has exposed the catchment to recurrent drought (Wondumagegnehu et.al, 2007). The catchment contains 10 Woredas and 168 Tabias. Among these woredas' four of them, Wukro, Atsebi-wemberta, Saharti-Samre and tanqua-abergle, were selected for this study.

2.2 DATA COLLECTION METHOD

The data for the study was collected from primary. The main source of primary data was the household survey collected by MU-IUC socio-economic research project during July and August 2009. The data were gathered through a smallholder farmer questionnaire administered to 734 households with information collected at household member level.

Here MU-IUC project uses both Cluster and Stratified sampling methods together with simple random sampling tool. A three stage sampling technique was used to collect the data. Initially, the Woredas in this catchment were grouped into clusters on the basis of their differences in agro-ecology zone (Kolla, Weina Dega and Dega). Accordingly, four woredas were randomly selected out of ten. These are Atsebi-wemberta (highland - Dega), Wukro (midland – Weina Dega), Saharti - Samre (midland- Weina Dega) and Tanqua-Abergle (lowland – Kola). Then, sample of eight tabias (two tabias from each woreda) were randomly selected. The tabias selected are representative of the three agro-ecological zones of the region. Finally, total sample of 734 households were randomly drawn from the selected tabias from a list of eligible households.

The survey data contain detailed information on household characteristics, household composition, asset ownership, credit, food and non-food expenditure and non-agricultural activities, land and its use, inputs, crop outputs and sales of previous year harvests, land rent, livestock ownership, livestock expenditure and income, adoption of modern input, crops and improved animals and access to extension services etc

2.3 DESCRIPTIVE STATISTICS OF INPUT - OUTPUT VARIABLES USED IN THE EFFICIENCY MODEL

In this section, the characteristics of the key variables that are used in efficiency estimation are depicted. Besides, a comparison of these variables statistics with the participant and non-participant households was made.

The average output value of the sample households was 9108.1 Birr. When we compare the two group's average output value, participant households have higher average value of output (12638.1 Birr) than the non-participant ones that was 5105.9 Birr. This result reveals that participation in extension service leads to an increase in households' income that obtained from crop production. The t-test result indicates that there was a significant difference between the participant and non-participant households output.

Table 1: Summary of descriptive statistics for input- output variable

Variable	Non-participant			participant			Total			t test
	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	
Output	344	5105.9	9889.5	390	12638	97621.7	734	9108.1	71536	-4.80***
Plot Size	344	4.16	5.47	390	4.90	3.41	734	4.6	4.50	-5.13***
Seed	344	414.37	429.0	390	518.37	389.91	734	469.6	411.7	-5.18***
Labor	344	54.52	51.48	390	71.16	51.68	734	63.36	52.22	-5.25***
Fertilizer	344	178.39	231.91	390	238.54	252.954	734	210.35	245.0	-4.95***
Manure	344	1235.5	9242.8	390	1343.5	7748.37	734	1292.8	8475.8	-2.73***
Oxen days	344	14.18	12.37	390	17.97	11.71	734	16.19	12.16	-5.12***
Agricultural Equipment	344	741.65	4529.6	390	796	1295.64	734	770.8	3239.2	-0.22

*** Significance at 1% level.
Source: computed from MU-IUC data 2009/10

The average labor used by the sample households was 63.36 man - day[3]. The mean labor used by the participant households was 71.16 man-day where as for non participant the average labor was 54.52 man- day. This result indicates that extensive labor use applied by the participant households than the non-participant ones. The higher man-day of participant household can be explained by various reasons such as longer harvesting seasons, higher value for the outputs which in turn allows households to hire more of seasonal workers. Labor also has significance

[3] man-day refers to the number of days spent by the family member as well as hired labor to plough, weed and harvest

difference between participant and non-participant farmers. In addition as indicated above in topic 4.1.2 the current mean farm size of the sample household is 4.6 tsimad.

Seed is one of the most important factors of production that helps to improve farm productivity. Farmers in the study area used both local and improved seed in crop production process. The average value of total seed used by the respondent farmers was 469.6 Birr and when we compare the two groups' participant farmers used 518.37 Birr value of seed and non-participant farmers spent 414.37 Birr for purchasing seed to use in the production process. The sampled households also spent on average 210.35 Birr for purchasing inorganic fertilizer. Moreover, both seed and fertilizer have significant differences on participant and non-participant households since the t-test result was significant at 1% level.

Animal power was also used in the production process and the mean animal power of sample respondent was 16.19 oxen-days[4]. When we compare the two groups' participant households have higher oxen- day (17.97 oxen-days) relative to the non-participant households (14.18 oxen-days).In addition, most farmers use hand hoes, ploughing set (mahresha), spade, sickle, and hammer as agricultural equipment. The mean value of agricultural equipment of the sampled household was 770.8 Birr and the mean value of the agricultural equipment for participant and non-participant households were 796 Birr and 741.65 Birr respectively. This implies that participant households have more agricultural equipments than the non-participant ones. Finally, the average quantity of manure applied on the farm by the sampled households was 770.8 Kg. In case of extension participant the mean manure quantity was 1295.64 Kg and for non-participant households the average manure quantity used was 741.65 Kg. The result shows that extension participant households were produce more quantity of manure than non participant households. The t-test result also shows that there was significant difference between participant and non-participant households in manure usage but they have no significant difference in relation with agriculture equipment value.

4. RESULTS AND DISCUSSION

4.1 SELECTION OF FUNCTIONAL FORM AND HYPOTHESES TESTS

The computer program, FRONTIER version 4.1 was used to get the maximum likelihood estimates of the parameters of the Cobb-Douglas and translog stochastic frontier production function and inefficiency effects model. Since results can be considerably affected by the choice of functional form in an empirical study. Cobb-Douglas and translog are the most commonly used functional forms in technical efficiency analysis. Translog or flexible functional form is generally preferred, since it does not need to impose general restrictions on the parameter nor the technical relationships among inputs (Kebede, 2001). Following log likelihood ratio test and rejection of the alternative hypothesis, the Cobb-Douglas production function form has been used to estimate stochastic frontier production function and inefficiency effect model.

The value of the logarithm of the likelihood function for the Cobb-Douglas and translog frontier model for the extension non-participant is -470.5 and -453.6, respectively. The generalized likelihood ratio test was used to decide the functional form as follows:

$$\text{LR test} = -2[\ln(H_0) / \ln(H_1)]$$

$$\text{LR test} = -2[\ln(H_0) - \ln(H_1)]$$

$$= -2[-470.5 - (-453.6)]$$

$$= 33.8$$

The value of the likelihood ratio test statistics was found to be 33.8 which is less than the critical chi square table value of 41.3 with 28 degree of freedom (the difference between the numbers of parameters of the two models) and at 5% significance level. So we accept the null hypothesis and thus, Cob-Douglas functional form was preferred over translog functional form for extension non-participant households.

[4] oxen-day is the sum of the number of days of oxen used for all activities

Table 2: Generalized likelihood-ratio tests of hypotheses for functional form and parameters of technical inefficiency. Source: computed from MU-IUC data 2009/10

Program	Log likelihood statistics of H_0	Test statistics LR	Degrees of freedom	Critical value $\chi_v^2{}_{0.95}$	Decision
Extension non-participant					
H_0: $\beta_8 = \beta_9 = \beta_{10} = \ldots = \beta_{35} = 0$	-470.5	33.8	28	41.3	Accept CD
H_0: $\gamma = \delta_0 = \delta_1 = \delta_2 = \ldots = \delta_7 = 0$	-573.0	205	9	16.3	Reject H_0
H_0: $\delta_0 = \delta_1 = \delta_2 = \ldots = \delta_7 = 0$	-560.1	179.2	8	14.9	Reject H_0
Extension participant					
H_0 : $\beta_8 = \beta_9 = \beta_{10} = \ldots = \beta_{35} = 0$	-573.0	24.4	28	41.3	Accept CD
H_0: $\gamma = \delta_0 = \delta_1 = \delta_2 = \ldots = \delta_7 = 0$	-640.2	134.4	9	16.3	Reject H_0
H_0: $\delta_0 = \delta_1 = \delta_2 = \ldots = \delta_7 = 0$	-633.2	120.4	8	14.9	Reject H_0

For the extension participant, Cob-Douglas and translog production functional form were estimated and the log likelihood function given by -573 and -560.8 respectively (see appendix 3). The generalized likelihood ratio test statistics was given by:

$$\text{LR test} = -2[\ln(H_0) - \ln(H_1)]$$
$$= -2[-573.0-(-560.8)]$$
$$= 24.4$$

The estimated LR test statistics value was significantly lower than chi square table value of 41.3 with 28 degree of freedom and at 5% level of significance. This implies that translog functional form was not an adequate representation for the given data set of participant households. Thus Cob-Douglas functional form also selected for the extension participant. In fact, in a technical efficiency analysis, functional specification has a small impact (Kopp and Smith, 1980).

In spite of the magnitude and significance of the variance parameter, γ, it was also important to examine various null hypotheses. For this purpose, various restrictions were imposed on the original model. To test the validity of these restrictions, the generalized likelihood ratio tests were performed. The result of these tests of hypothesis for the parameter of the Cobb-Douglas stochastic frontier and inefficiency model were performed.

The other null hypothesis was concerned with technical inefficiency effects. It states that technical inefficiency was absent. Based on the generalized log-likelihood ratio test, we find test statistics[5] for the two groups were 205 (for non-participant) and 134.4 (for participant) which are significantly higher than the critical value of 16.3, suggesting that the null hypothesis of no technical inefficiency effect was rejected. Therefore, this result points out that the traditional average (OLS) production functions was not appropriate representation of the sampled data.

The final important null hypothesis was concerned with influence of farm specific factors on technical inefficiency associated with participant and non-participant households. The generalized likelihood ratio statistics for the two groups were 179.2 (for non-participant) and 120.4 (for participant) and the test statistics was found to be significantly higher than the critical values of 14.9. Therefore, the null hypothesis that farm specific factors have no effect on technical inefficiency was rejected for both groups. This result indicates that the joint effect of these variables on the level of technical inefficiency is significantly different from zero.

4.2 MAXIMUM LIKELIHOOD ESTIMATE FOR THE STOCHASTIC PRODUCTION FRONTIER

Maximum likelihood estimates of parameters of the two-equation system given by equations (9) and (10) are reported in tables 4.8 and 4.9. The parameters were estimated in a three-step procedure. First OLS estimates of the frontier

[5] Kodde and palm (1986) present the percentile values for these distributions.

are calculated. These estimates are unbiased except for the intercept term. Then, a two-phased grid search of γ was conducted with the β parameters set to the OLS estimates obtained in the first step. In addition, the intercept and σ^2 were adjusted using a corrected ordinary least squares method, and σ parameters were set to zero. The third step involves using the values selected from the grid search as starting values to obtain the final maximum likelihood estimates.

The maximum likelihood estimates of the parameters of the selected Cobb-Douglas model for extension participant and non-participant are given in table 4.8 below. The ratios of the estimated coefficients to their corresponding standard error were used to test the statistical significance of the parameters. It was evident from table 4.8 the estimate of the coefficients of the parameters associated with the production inputs for the data set of non-participant household were statistically different from zero for plot size, fertilizer and agricultural equipment value at 10%, 1% and 1% level of significance respectively. The rest input variables were not statistically different from zero and their coefficient signs were as expected. However, in the case of extension participant farmers, the numbers of significant variables were increased to four and the sign of the estimated coefficient were positive except labor and manure which were statistically insignificant. Therefore, for participant households plot size, fertilizer, oxen and agricultural equipment value were significant at 5%, 10%, 1% and 10% level of significance respectively.

Table 3: Maximum Likelihood Estimates of Parameters Associated With Agricultural Inputs Included in the Stochastic Production Frontier Analysis

Variables	Non-Participant(344)		Participant (390)	
Inoutput	ML Estimate	t ratio	ML estimate	t ratio
Intercept	7.3***	37.0	7.2***	23.96
lnplotsize	0.21*	1.67	0.12**	2.10
lnseed	0.0003	0.45	0.001	1.28
lnlabor	0.002	0.87	-0.0004	-0.02
lnfertlizer	0.09***	3.07	0.05*	1.78
lnmanure	0.01	0.29	-0.01	-0.64
lnoxen	0.01	0.43	0.09***	3.80
lnariequip't	0.11***	2.74	0.08*	1.81
σ^2	2.48	8.08	3.12	5.10
γ	0.80	28.4	0.77	14.65
Log-liklihood function	-470.4		-573.0	

***significant at 1%, **significant at 5%,*significant at 10%
Source: computed from MU-IUC data 2009/10

4.3 OUTPUT ELASTICITY AND RETURNS TO SCALE

Economic interpretation of estimated coefficients of the Cobb-Douglas production function can be made based on production elasticties. Table 4.8, shows the elasticity of output with respect to each input for non-participant and participant households. The elasticties of output with respect to inputs at the point of approximation are given by the first-order coefficients of the Cobb-Douglas production function.

Plot size (land): Land remains a key input in the production of crops for both groups. The output elasticity of agricultural land was generally higher than the other input elasticties for both extension participant (0.12) and non-participant (0.21) households. It was also statistically significantly different from zero. This shows that land was the most critical input for these farmers. This result reveals that one percent increase in plot size leads to an increase in output of participant and non-participant households' by 0.12% and 0.21 % respectively.

Fertilizer: The output elasticties of chemical fertilizer have the expected sign and statistically significantly different from zero both for extension participant non-participant households. The output elasticity for fertilizer variable was 0.09 and 0.05 for non-participant and participant households respectively. This result reveals that one percent increase in the use of fertilizer leads to an increase in output of non-participant and participant farmers by 0.09% and 0.05 % respectively.

Oxen-day: The output elasticties of oxen-day have had the expected sign for both programmers' even if it was insignificant for non-participant households. However, output elasticity of oxen-day for participant farmers were higher (0.09) than the non-participant ones. In addition, oxen-day variable statistically significant for participant households this implies that one percent increase in oxen-day leads to an increase in output by 0.09 percent.

Agriculture equipment: The output elasticity of farm equipment had positive signs for both participant and non participant households and statistically different from zero. The output elasticity indicates that one percent increase in farm equipment leads to an increase in 0.11 % and 0.08 % of output for the non-participant and participant households respectively.

The rest inputs like seed, labor and manure are statistically insignificant for both participant and non-participant farm households. The economic reasons for the insignificance of seed might be farmers were used beyond the quantity of seed recommended by the extension agents. On the other hand, the statistical insignificance and negative elasticity of labor could be the abundance of labor (high labor-to-land ratio) in the area and the low marginal productivity of labor after a certain level of labor. Finally, the negative elasticity and statistically insignificance of manure for extension participant might be due to the usage of manure beyond the recommended level of for each plot.

The returns to scale parameter for the Cobb-Douglas production frontier was estimated by the sum of the elasticties of the number of input variables used in the production function (Batesse and Sarfruz, 1998). The sum was then used as an indicator of returns to scale. The estimated returns to scale parameter for non-participant and participant households were 0.42 and 0.33 respectively which means both groups operate at decreasing returns to scale. The most common source of decreasing returns to scale is lack of increasingly complex management and mechanized farming sys

4.4 TECHNICAL EFFICIENCIES OF FARM HOUSEHOLDS

Stochastic frontier analysis was performed to examine relative crop production efficiency among farmers in the study area. Technical efficiency (TE) reveals whether the farmer uses the best available technology in the production process or not. The software program (FRONTIER 4.1) used in this study gives the level of technical efficiency of each individual farmer and the cumulative and frequency distribution of the technical efficiencies of both extension participant and non- participant households are presented in table 4.9 below (see also appendix 6.4).
The farm-specific technical efficiency was segregated into non-participant and participant households. Table 4.9 shows that the mean level of technical efficiency of sample farm household was 53% and it ranges from the lowest efficiency of 7% to the highest 90%. This result indicates that households were not fully efficient and they far from the potential production frontier on average 47%. In general, the result suggests that there exists a great potential to increase crop production in the study area beyond the current production level.

When we compare the two groups, the predicted technical efficiency for non-participant household ranges from 13% to 88% with mean of 52% implies that there exist huge potential to increase crop production in the study area. In addition it indicates high level of technical inefficiency problems existed among non-participant households in the study area. In the case of participant farmers the mean level of technical efficiency level was 57% and it ranges from 7% level of technical efficiency to 90% level of technical efficiency. Therefore, if we compare these groups, participant households' technical efficiency better than the non participant ones even though still there was huge difference between the potential outputs and the actual output of the two groups. The mean technical efficiency of the two groups indicated that participant farmers were deviated from the potential production frontier curve on average by 43% and the non-participant farmers far from it on average by 48%.

Table 4, revealed that 29.1% out of the sample households (96 farmers from participant and 118 farmers from non-participant) were operates below 50% technical efficiency levels. Therefore, this implies that relatively more non-participant farmers were situated below 50% technical efficiency level than the participant ones. On the other hand, 7 farmers from each group had TE above 85% of technical efficiency which indicates that only 2% of the sample farmers have a technical efficiency greater than 85%. Further analysis reveals that 69.2% of the sample households (221 non-participant and 287 participant farmers) have TE ranges from 50% to 85%. This result suggests that most crop producers in the study area operating far from the potential production frontier.

Table 4: Frequency distribution of technical efficiency indices for the two groups

Efficiency score	Non-participant(N=344)	Participant (N=390)	Total(734)
TE<0.5	118	96	214
0.5≤TE<0.6	49	82	131
0.6≤TE<0.7	90	114	204
0.7≤TE<0.8	55	81	136
0.8≤TE<0.85	25	10	35
TE≥0.85	7	7	14
Mean	0.52	0.57	0.53
Minimum	0.13	0.07	0.07
Maximum	0.88	0.90	0.90

Source: computed from MU-IUC data 2009/10

4.5 TECHNICAL INEFFICIENCY EFFECTS MODEL

Various socio-economic and demographic factors are expected to affect the efficiency of farm households. The parameter estimates of the inefficiency model also have an important contribution for the study. Using the specification of equation (3.16) the study makes an attempt to investigate determinants of technical inefficiency. The estimates for the variance parameters σ^2 and γ were statistically different from zero for both participant and non-participant farmers. This indicates statistical confirmation of our presumption that there are differences in technical efficiency among farmers. The ML estimate of γ for extension non-participant was 0.80 and for participant 0.76 which were significantly different from zero. It was observed that the farm specific variability contributed about 80% and 76% variation in yield among the non-participant and participant farmers respectively, which implies that about 80% for non-participant and 76% for participant farmers' differences between the actual and maximum production frontier outputs are due to differences in farmer's levels of technical inefficiency and not related to random variability.

With regard to the sources of efficiency differentials among sample of selected non-participant and participant households, the estimates of technical inefficiency effects model provide some important insights. The parameter estimates in table 4.10 have relevant signs, indicating the impacts of explanatory variables on the technical inefficiency. Out of seven variables explaining technical inefficiency in the case of non-participant households two of them are statistically significant and have the expected signs. On the other hand in the case participant households three of them out of seven explanatory variables are statistically different from zero.

Table 5: Maximum Likelihood Estimates of Inefficiency Model Parameter

Explanatory Var.	Non-Participant(344)		Participant(390)	
	ML estimate	t ratio	ML estimate	T ratio
Intercept	3.41***	7.9	3.04***	5.50
Plotdistance	0.00	-0.16	0.0054***	6.83
Accesswage	0.70*	1.67	-0.22	-0.52
Improvedseeds	0.13	0.13	-0.13	-0.13
Inofertilizeruse	-0.15	-0.30	-0.86**	-2.20
numbcrop	-1.93***	-11.96	-1.7***	-10.53
Depratio	0.10	0.53	0.029	0.52
Plotsize	-0.013	-0.34	0.122	0.57

***significant at 1%, **significant at 5%,*significant at 10%
Source: computed from MU-IUC data 2009/10

Plot distance: Plot distance of the household was included in the inefficiency equation to examine the effect of wasting time (to go from residence to the specific plot) on efficiency. In the case of non-participant household the effect of plot distance was not different from zero. On the contrary for participant households plot distance was significant at 1% and it has positive sign of the estimated value of the variable. The positive sign supports the argument that farmers become less efficient when their plot far from their home they live since they spent much time to go to the plot.

Access for wage income: wage income access of the household was included in the model to examine whether the existence wage access has any effect on efficiency or not, the parameter estimate of this variable was positive and significant at 10% for non-participant households. On the contrary the parameter estimate of the variable for participant farmers is negative and insignificant. Therefore, it is arguable that the positive sign of the estimated coefficient of non-participant farmers implies that people that have access for wage are less efficient than those that have not access for wage income. This result may imply something that is inherent when families have access to off farm income not produce crop efficiently relative to those do not have access for wage since they focus both on the crop production and wage income. However, households that do not have access for wage income give more attention for crop production and they become less inefficient. On the contrary, according to Weldehana (2000), by enabling farm households to engage in both farm and off-farm activities, it might be possible to make farmers more efficient thereby increasing the productivity of agriculture.

Inorganic fertilizer: inorganic fertilizer use variable was included to examine whether inorganic fertilizer use has any effect on efficiency or not, the parameter estimate of this variable was negative both for extension non-participant and participant farmers but significant only for extension participant households at 5%. The negative sign of the estimated coefficient implies that farmers that use inorganic fertilizer are more efficient than those that do not use inorganic fertilizer. In other words, use of inorganic fertilizer reduces farmers' inefficiency level and leads to an increase in productivity.

Number of crops produced: This variable also included in the inefficiency model whether crop diversification affects technical inefficiency or not. The parameter estimate of this variable was negative and statistically different from zero for extension participant and non-participant farm households. This means currently farmers growing more than one crops leads to have higher efficiencies than farmer growing only one crop. Even if cultivating a number crop of requires diverse activities, diversification has an advantage of full utilization of family labor through the diversified activities required for the different crops grown. Crop diversification also allows farmers to produce marketable crops in addition to consumption. When producers are able to improve efficiency through crop diversification, they will improve their capability of efficiently producing crops and increase their income beyond consumed food crop. Moreover, crop diversification has bigger role in commercialization of agriculture the agriculture sector.

As table 4.10 shows the parameter estimates of improved seeds use and plot size of the households were found have no significant effect on inefficiency of both for extension participant non-participant farmers even if the sign of the coefficients are different for the both groups.

5. CONCLUSION AND RECOMMENDATION

This study sets out to provide estimates of technical efficiency of crop producer in northern Ethiopia particularly in Geba-catchment and to explain variations in technical efficiency among farmers through improved technology use and socio-economic characteristics. This chapter presents the summary of main findings of the paper as well as important intervention to alleviate the problems.

5.1 CONCLUSIONS

Agricultural productivity varies due to differences in production technology, differences in the setting in which production occurs and differences in the efficiency of the production process. Efficiency measurement has been the concern of the researchers with an aim to investigate the efficiency levels of farmers engaged in crop production activities. Identifying determinants of efficiency level is a major task in efficiency analysis (Kebede, 2001).The study found that the mean level of technical efficiency of the sample households 53% which means that on average sample households far from the potential production function by 47%. Therefore, in the study area it is possible to increase crop production by 47% until farmers reached on the maximum attainable output. The mean technical efficiency of the two groups varied from 52% for non-participant households to 57% for participant households suggesting that crop yields in the study area could be improved using the existing available resource technologies efficiently for the two groups. However, TE ranges between 7 to 90 percent among the crop producers in the study area.

Elasticity of inputs was computed for both participant and non-participant households. In case participant household output could be increased through increasing factors of production like fertilizer, oxen-day and agricultural equipments since these inputs have significant effect on output elasticity. This implies a one percent increase in fertilizer use increases yield by 0.05%, while an increase in oxen-day and agricultural equipment value by one percent increase yield by 0.09% and 0.08 % respectively. On the other hand for non-participant farmers output would be increased through by increasing inputs like fertilizer and agricultural equipment. Therefore a one percent increase of fertilizer and agricultural equipment would increase output by 0.09% and 0.11% respectively. Extension participant farmers were relatively more efficient than the non participants.

Analysis of the determinant of technical efficiency also was carried out and it showed that technical inefficiency in crop production of non-participant households could be reduced through crop diversification the households. On the other hand, the study also showed that technical efficiency of participant farmers could be increased through crop diversification, increasing inorganic fertilizer use and proper use of the available farm resources efficiently. Therefore, crop diversification was a major tool to higher production efficiency for both groups.

5.2 RECOMMENDATIONS

The problem of food insecurity in Ethiopia has, to a large extent, been addressed by annual emergency food aid from abroad. During the past two decades, Ethiopia has been one of the largest recipients of food aid in Africa and the world (Little 2008).One of the most important avenues for reducing food aid is to increase yield per unit area by increasing technical efficiency. This study has been concluded that increase in input use (i.e. plot size, agriculture equipment and fertilizer) increases yield across the two groups. Given the empirical findings, the proposed recommendations were:

- It was evident from results of the study that farmers having access to extension services were relatively less technically inefficient. Even though government tries to expand the extension service program still there exists non-participant households or drop out from the program due to various reasons. Therefore, extension service should be expanded to the whole households that helps in increasing over all technical efficiencies of farmers and makes them food self-sufficient.

- Diversification of crops and use of inorganic fertilizer reduce technical inefficiency of farmers that leads to the change in the actual production frontier closer to the potential frontier. In addition, crop diversification absorbs excess labor that found in the rural farm families. Therefore, farmers should develop the culture of producing different variety of crops not only for reducing technical inefficiency but also for commercialization activity.

REFERENCES

Ahmed ,M. and Bravo-Ureta ,B.E.,(1996).Technical efficency measure for dairy farms using panel data – a comparison of alternetive model specifications. Journal of productivity analysis.

Aigner, D.,Lovell, C.A., and Schimidt, (1977).Formulation and Estimation of stochastic frontier production models. Journal of Econometrics 6:21-32 (1992).

Alemu, B.A, Nuppenau , and Boland, (2009). Technical Efficiency across Agro-Ecological Zones in Ethiopia: The Impact of Poverty and Asset Endowments.

Alemu, Z.G., (2005).Causes of Instability in Cereal Production in Ethiopia. Department of Agricultural Economics, Faculty of Natural and Agricultural Sciences at the University of the Free State

Arega, D., Alene , Rashid, M., Hassan , (2002).Measuring the Impact of Ethiopia's New Extension Program on the Productive Efficiency of Farmers. Pretoria.

Battese,G.E. and Sarfruz,S.,(1998).Technical Effiecency of Cotton Farmers In The Vehari District Of Punjab, Pakistan. Pakistan Journal of Applied Economics.

Battese,G.E.,(1992).Frontier production functions and technical efficiency: a survey of empirical application in agricultural economics.

Battese,G.E. and Coelli,T.J., (1995). Inefficiency Effects in a Stochastic Frontier production Function for Panel Data, Empirical Econometrics.

Belay, K., (2005). Agricultural extension in Ethiopia: the case of participatory demonstration and raining extension system. Ethiopia: vol no18,

Bravo-Ureta,B.E, and Pinherio, A.E.,(1993).Efficiency analysis of developing country agriculture: a review of the frontier function literature. Agricultural and resource economics review.

Chirwa, E.W., (2007).Sources of Technical Efficiency among Smallholder Maize Farmers in Southern Malawi Department of Economics Chancellor College University of Malawi AERC Research.

Coelli, T.J,(1995). "A Guide to FRONTIER version 4.1c: A Computer programme for Stochastic Frontier production and Cost Function Estimation": Working paper 96/07, Centre for Efficiency and Productivity Analysis Dept. of Econometrics, University of New England.

Endris, M, (2010). Determinant of technical efficiency and farm -level adoption of modern agricultural inputs:the case of Geba catchment. An M. Sc. Thesis Presented to the college of Business and Economics of Mekelle University. Ethiopia, Mekelle.

Gebreegziabher, Z., A. Oskam, and Tasawu,W., (2004). Technical Efficiency of Peasant Farmers in Northern Ethiopia: A Stochastic Frontier Approach.

Gebregziabher, G., Namara,R.E., and Stein Holden,S., (2008) Technical Efficiency of Irrigated and Rain-Fed Smallholder Agriculture in Tigray, Ethiopia: A Comparative Stochastic Frontier Production Function Analysis.

Geremew, G., (2005) Determinants of Productivity of Smallholder Farmers in Ethiopia: The Case of Wheat Production in Two Districts of Sidama Zone, M.Sc. Thesis, Addis Ababa University.

Jondrow, J, C.A Knot Lovell, vans Materov and Peter Schmidt,(1982). "On the Estimation of Technical Efficiency in the stochastic Frontier Production Function Model". Journal of Econometrics 19 no.2/3:233-38.

Kebede,T.,A.,(2001).Farm Household Technical Efficiency: A Stochastic Frontier Analysis, a study of Rice Producer in Mardi Watershed in the Western Development, Region of Nepal.A Master Thesis, Department of Economics and Social Science, Agricultural University of Norway, Norway.

Little, P.D.,(2008). “Food Aid Dependency in Northeastern Ethiopia: Myth or Reality?”

MoFED **,** (2006).A Plan for Accelerated and Sustained Development to End Poverty (PASDEP). Addis Ababa: Vol.1

Mulat, D., and Bekele, H.,(2003).The Determinants of Yield of Major Cereals: The Contribution of New Technologies in Selected Villages of Ethiopia.

Schultz, T.,(1964). Transforming Traditional Agriculture, University of Chicago Press.

Thaim,A., Bravo-Ureta ,B.E., and T.E. Rivas,(2001). Technical efficiency in developing country agricultures: a meata analysis.

United State Government initiative,(2010). Ethiopia five year 2010implementation plans.

Vu Tung,P.B., (2010).Technical Efficiency of improved Extensive Shrimp Farming in Ca Mau Province, Vietnam. An M. Sc. Thesis presented to the Norwegian college of Fisher science university of Tromso , Norway and Nhatrang university, vietnam .

Statement:
We hereby confirm that this research paper is our own original work and we have cited all sources that were used.

APPENDICES

Appendix 3.Output from the program FRONTIER (Version4.1c) for extension non-participant

	Coefficient	standard-error	t-ratio
beta 0	0.73061261E+01	0.19735095E+00	0.37020984E+02
beta 1	0.20702785E+00	0.12376734E+00	0.16727179E+01
beta 2	0.32774592E-03	0.72478079E-03	0.45220006E+00
beta 3	0.22734183E-02	0.26258755E-02	0.86577537E+00
beta 4	0.85873185E-01	0.27942723E-01	0.30731859E+01
beta 5	0.62003326E-02	0.20877149E-01	0.29699135E+00
beta 6	0.77442498E-02	0.17832855E-01	0.43426865E+00
beta 7	0.10851446E+00	0.39552843E-01	0.27435311E+01
delta 0	0.34116161E+01	0.43160480E+00	0.79044907E+01
delta 1	-0.54023272E-03	0.34245766E-02	-0.15775168E+00
delta 2	0.70172065E+00	0.42028840E+00	0.16696170E+01
delta 3	0.13134909E+00	0.10266718E+01	0.12793679E+00
delta 4	-0.15492742E+00	0.51627285E+00	-0.30008825E+00
delta 5	-0.19312827E+01	0.16138323E+00	-0.11967059E+02
delta 6	0.10195675E+00	0.19357529E+00	0.52670332E+00
delta 7	-0.13292800E-01	0.38558059E-01	-0.34474765E+00
sigma-squared	0.24832350E+01	0.30741830E+00	0.80777072E+01
gamma	0.80191846E+00	0.28261207E-01	0.28375238E+02

Log likelihood function =-0.47049877E+03

LR test of the one-sided error = 0.20502387E+03

Mean efficiency = 0.52697031E+00

Appendix 4.Output from the program FRONTIER (Version4.1c) for extension participant

	Coefficient	standard-error	t-ratio
beta 0	0.72032846E+01	0.30069389E+00	0.23955540E+02
beta 1	0.12406102E+00	0.59203016E-01	0.20955186E+01
beta 2	0.83998031E-03	0.65878352E-03	0.12750476E+01
beta 3	-0.39905807E-04	0.22495658E-02	-0.17739338E-01
beta 4	0.46400651E-01	0.26134297E-01	0.17754697E+01
beta 5	-0.12291997E-01	0.19174911E-01	-0.64104586E+00
beta 6	0.89124477E-01	0.23468164E-01	0.37976757E+01
beta 7	0.80131462E-01	0.44157454E-01	0.18146758E+01
delta 0	0.30436601E+01	0.55291731E+00	0.55047293E+01
delta 1	0.54483815E-02	0.79766660E-03	0.68303995E+01
delta 2	-0.22045919E+00	0.42798512E+00	-0.51510948E+00
delta 3	-0.13080143E+00	0.99566994E+00	-0.13137027E+00
delta 4	-0.86030077E+00	0.39157281E+00	-0.21970391E+01
delta 5	-0.17075535E+01	0.16216680E+00	-0.10529612E+02
delta 6	0.29436079E-01	0.56156019E-01	0.52418385E+00
delta 7	0.12285624E+00	0.21411174E+00	0.57379497E+00
sigma-squared	0.31158489E+01	0.61071196E+00	0.51019943E+01
gamma	0.76525694E+00	0.52235585E-01	0.14650108E+02

Log likelihood function =-0.57307646E+03

LR test of the one-sided error = 0.13433067E+03

Mean efficiency=0.57029596E+00

Appendix 6.7 Frequency Distributions of Technical Efficiency Indices for non-participant, participant and total