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Analysis of Small Scale Irrigation Users' Household on Farm Production Efficiency Among Smallholder Farmers: the Case of Horo District, Ethiopia

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Abstract: Agriculture is the mainstay of the country's economy and the major source of foreign exchange earnings and domestic consumption. To improve the prevailing low level of production and productivity the use of yield improving inputs is of paramount important. As the potential to increase production by bringing more resources into use became more and more limited, the efficiency with which the farmers use available resources has received the utmost attention. This being the case, in this study, an attempt was made to examine comparative analysis of small scale irrigation users household on farm production efficiency among smallholder farmers. Both the descriptive and econometric model analysis were used. The survey data collected considered two groups of farm households, irrigation users and irrigation non-users households. Stochastic frontier production function with farm specific technical inefficiency variables was used to estimate technical efficiency. Among the input variables, farm size and capital were found to significantly influence agricultural output. Access to irrigation was found to significantly improve the technical efficiency of household. The whole sample mean technical efficiency of irrigation user and irrigation non-user households was 79.5%. This implies that agricultural output can be increased on the average by 20.5 percent if technical efficiency of farming households improved to obtain the maximum attainable level of output.

Keywords: Stochastic Frontier Analysis, Small Scale Irrigation, Technical Efficiency

1. Introduction

Ethiopia is found in the horn of Africa having area coverage of about 1.2 million square kilometers. It is endowed with rich biological diversity. The country blessed with abundant water resource for irrigation [1]. In fact, the agricultural system does not yet fully benefited from irrigation potential [14]. The irrigation coverage of Ethiopia is less than 5% which makes the households' agricultural production to remain brunt on rain-fed agriculture [18] and low income to be generated.

Agriculture in Ethiopia is operated by smallholder farmers, where 80% of the people that predominantly depend on it for ensuring their livelihood. The sector remains at subsistence level [12] failing to feed the ever exploding population.

Consequently, special attention has been paid to the areas with high rainfall variability, high land degradation and high moisture deficit to tackle the problem of food insecurity [10]. The use of supplementary irrigation from either traditional or modern water harvesting structures is considered as the primary measure to be taken against the problem. In this direction, the FDRE government of Ethiopia is making serious efforts by allocating fairly large amount of budget for the development of infrastructures including water irrigation accessibility and use [2].

Small scale irrigation boosts agricultural production and thereby increases income of households in rural areas [19]. It also increases crop productivity and ensures household food security [15]. Despite the fact that Ethiopia has around 122 billion m^3 volume of water that runoff annually from its 12 river basin [27] irrigation coverage is low [18]. Numerous studies outlined attributable factors like poor performance of irrigation systems [15], inequitable, unreliable and lack of water storage and supplies [27], and physical, socio-cultural and economic constraints [25]. Large areas within the irrigation systems suffer from severe water shortages, resulting in declining of productivity and income of households [6].

Horo District is an irrigation potential area, with an estimated 5,483 hectares of water bodies [16]. However, the living standard of the community is subsistence. Therefore, in this study, comparative analysis of small scale irrigation users household on farm production efficiency among smallholder farmers were examined at household level. To this end, this particular study was aims at investigating whether access to irrigation has comparative analysis of small scale irrigation users' household on farm production efficiency among smallholder farmers.

FAO report that agriculture is known to be the dominant source of food production and an important sector for sustaining growth and reducing poverty in many developing countries [13]. Looking in Ethiopia, agricultural production in Ethiopia is primarily rain fed, so it depends on erratic and often insufficient rainfall. As a result, there are frequent failures of agricultural production [5].

Irrigation has the potential to stabilize agricultural production and mitigate the negative impacts of variable or insufficient rainfall) [23]. Irrigation increases agricultural productivity and farm income per ha, according to previous studies [24].

The use of irrigation is one of the spectrums of technologies available to increase agricultural production. And one can also sense that there is an observable income gap between farmers using irrigation and non-users of irrigation [19].

Irrigation is assumed to improve technical efficiency of crop production and income of households. However, it is not well known to what extent the households using irrigation are better off than those who non-user of irrigation and whether there exist variability in technical efficiency among the user and non-user irrigation, so far no specific investigation is made in this respect. Therefore, this study will assess to compare small scale irrigation users household on farm production efficiency among smallholder farmers.

2. Research Methodology

2.1. Description of the Study Area

Horo district is located in Horo Guduru Wollega Zone of Oromia Regional State, at about 314km west of Addis Ababa capital city of Ethiopia. Geographically, it is located between $9^0$34'N latitudes and 37^0 06'E longitudes [16]. The district is bordered by Jarte Jardaga district in the North, Jimma Ganati district in the South and East South, and Abe Dongoro district in the West and Abayi Choman district in the east.

According to HWAO, the total population of Horo district was 76,162 of these 73,983 and 2,179 were rural and urban population respectively [16]. Similarly, 38,256 are females and 37,906 are males in the District. In each, 36,811 are males and 37,172 are female in rural, whereas 1,095 are males and 1,084 are females in urban area. Like other parts of the highlands of the country, there are mixed cultivation of livestock rearing and crop production, in which subsistence agriculture is the main economy development of the community.

The information of temperature and rainfall data for this study was obtained from Shambu Meteorological Station. The distribution of rainfall is unimodal, characterized by a prolonged wet season from June to September and a short dry spell showers from mid-February to April. There is a long dry period from October to the end of February. Based on data obtained from Shambu Metrologist station, the mean annual rainfall in the study area is about 1566 mm [26]. The mean annual temperature is about 16.6°C and the mean minimum temperature is 10.78°C whereas the mean maximum temperature is 22.32°C. There is slight temperature difference throughout the year. The hottest months are from February to May maximum temperature recorded is about 24.6°C (in April/May) and the coldest months are from July to December with the mean minimum temperature 9.8°C (in December). Based on altitudinal variations, Horo District has three Agro-Climatic Zones which correspond to the classification systems: 43% Dega (2500-3500 m) 55.56% Woina Dega (1500 -2500 m), and 1.24% Kola (500-1500 m) [26].

2.2. Sampling Techniques

In this study, out of twenty two kebeles of the district, three kebeles was purposively selected supposing better irrigation potential. The total households in the three Kebeles were stratified into two strata: irrigation user and non-user households. The lists of total irrigation user households in the selected Kebeles were obtained from the District Irrigation Development Authority and the number of non-irrigation user households in the selected Kebeles was obtained from their respective kebele administration. The irrigation users and non-users were selected from the three selected Kebeles of the district to ensure homogeneity of factors except irrigation. Then, the sample respondents from each stratum were selected via probability proportionate to size procedure. Accordingly, 128 respondents were selected from the three Kebeles.

General, the district as a whole and the specific study area particularly are purposively selected using the following criteria.

1) Almost more than half of districts highland, where there is relatively irrigation potential available and good irrigation practices known [16].
2) Horo district has a long history of traditional irrigation practices and indigenous knowledge. And hence, it is possible to grab the opportunities and capitalize on [16].
3) There are relatively better irrigation activities in the study area that gives opportunity to government in developing modern small-scale irrigation schemes [16].

The sampling design of this study was involve a stratified random sampling technique, with non-users and user of irrigation. Both probability and non-probability sampling methods was employed in sampling and selection process. Probability sampling was used to generalize the result from the sample to the household, allow to calculate the exactness of the estimates obtained from the sample and to specify the sampling error. Non probability sampling techniques can be used hence the district was selected purposively.

2.3. Types, Source and Methods of Data Collection

In this study, both primary and secondary data were utilized. To obtain primary data, semi-structured questionnaire with both closed and open-ended questions was developed. Three enumerators, who are fluent speakers of the local language, Afaan Oromo, was recruited from their respective selected Kebeles and an intensive training on data collection procedures, interviewing techniques and the detailed contents of the questionnaire was given to them. The questionnaire was translated into to Afaan Oromo to allow enumerators better understand the questions and properly administer the interviews.

On the other hand, necessary care was taken in recruiting the enumerators and strict supervision was made during the course of survey work for the sake of the successful achievement of the study. Personal observations of physical features, informal a discussion with farmers and agricultural extension workers of the selected Kebeles was also be made as necessary.

Moreover, secondary data was obtained from different literatures, published thesis and document data of respective organization, (District Irrigation Development Authority, District Office of Agricultural, District Office Rural Land and Environmental Protection) etc.

2.4. Methods of Data Analysis

To address the objectives of the study, both descriptive analysis and econometric methods were employed. For this study, preliminary statistics such as mean, percentages, standard deviation, chi-square and t-test were used.

Technical efficiency determinant typically include education, geographical distribution, specialization, participation in program of any kind, etc [7]. A Cobb-Douglas production function is applied to estimate the average production function. The estimated average production function is compared with the frontier of all observation. Deviations from single observations to the average production function frontier provide measures of technical inefficiency. Obviously, random deviations (white noise) can significantly affect the degree of deviation of each observation from the average production function frontier and thereby affect the measure of technical efficiency [7]. To address this problem, as it is cited in [7], the consideration of random variable (white noise) in technical efficiency analysis was developed by [4]. For estimation of technical efficiency and agricultural production of households, the stochastic production frontier of Cob-Douglas production function type was employed, which is indicated as follows.

$$Y_i = f(xi, \beta)\, e^{\varphi} \tag{1}$$

Where: Y_i is the annual total agricultural output of household expressed in monetary value (in Birr). f (xi, β) and e^{φ}, respectively, represent the deterministic part and the stochastic part of the production frontier, φ represents the random error term, and β is a vector of parameter to be estimated. Besides allowing for technical inefficiency such stochastic production frontier models also acknowledge the fact that random shocks outside the control of the farm operator can affect output. But more importantly, the stochastic production frontier models provide a great virtue that the impact of shocks due to variations like in vagaries of weather, etc on output can at least in principle be separated from the contribution of variation in technical efficiency [20]. To analysis technical efficiency, OLS model was employed. The relationship between the variables and the hypothesis regarding these variables was tested.

A Cobb-Douglas functional form which includes both the conventional inputs and exogenous factors believed to affect inefficiency was the one considered in this specific study. The final version of the model estimated is indicated as below.

$$\ln Y = \beta_0 + \beta_1 \ln L + \beta_2 \ln H + \beta_3 \ln K + \beta_4 \ln OX + \delta 0 + \delta_1 Age + \delta_2 L + \delta_3 DDA + \delta_4 PEXT + \delta_5 IRR + \varepsilon \tag{2}$$

Where,

Yi represents the monetary value (in Birr) of annual total crop output of household

$\beta_1, \dots, \beta_4$ are the coefficients of parameter estimates of input variables

L-Represents the total cultivated land holding of household in ha

H- is total human labor in man-days utilized

K -represents total value (Birr) of other agricultural inputs utilized

OX-is a total ox power (oxen-days) utilized

Age- is age of household head (years)

DDA- represents distance (hour) between the development centers and the sampled household residence

PEXT- is a dummy variable having the value of 0, if household has participated in the extension package program and 1 if household did not participate in extension package program,

IRR- is a dummy variable having value of 0 if household has access to irrigation technology and value of 1 if household has no access to irrigation technology

$\delta_1, \dots \delta 5$- are the coefficient of parameter estimates of the inefficiency variables and

ε-is the disturbance term included in the model.

For both income level and technical efficiency of small scale irrigation was statistically desirable to sort out problem of multicollinarity among the continuous variables and check the association among discrete variables before estimating a model. The term multicollinarity refers to a situation where two or more explanatory variables can be highly linearly related. The consequences of multicollinarity are as follows. In the case of perfect multicollinarity we cannot estimate the individual regression coefficients or their standard error.

In case of high multicollinarity individual coefficients can be estimated and the OLS estimators retain BLUE property, but the standard errors of one or more coefficients tend to be large in relation to their coefficient values.

Multicollinarity is essentially a sample (regression) phenomenon in the sense that even if the X variables are not linearly related in the population (i.e, population regression function), they can be so related in particular sample. When we postulate the population regression function (PRF), we believe that all X variables included in the model have a separate or independent effect on the dependent variable Y. But if it was happen that in any given sample that is was to estimate the PRF some or all X variables are so highly collinear that we cannot isolate their individual influences on Y.

For all these reasons, the fact that OLS estimators are best linear unbiased estimators (BLUE) despite (imperfect) multicollinarity is of little help in practice to consider that the estimation and hypothesis testing are free from flaws [26].

Therefore, the correlation coefficients and a variance inflation factor (VIF) techniques was employed to detect the problem of multicollinarity (Gujarati, 2006). In the case of the VIF factor technique, each selected explanatory (X_i) was regressed on all other explanatory variables, the coefficient of determination (R_i^2) constructed in each case was evaluated to detect whether multicollinearity is a serious problem.

$$\text{VIF}(\beta_i) \text{ is defined as, VIF}(\beta_i) = (1-R_i^2)^{-1} \quad (3)$$

Where, R_i^2 is the squared multiple correlation coefficient between X_i and the other explanatory variables [21].

3. Results and Discussions

This chapter is devoted to present results and discuss the main findings.

3.1. Descriptive Results

This section describes the analysis of survey data and its interpretation. In the first section, the sample households‟ demographic characteristics are discussed. Particular reference is given to the factors hypothesized to influence income, such as family size, education level, land holding, asset holding, labor availability, access and source of credit for irrigating and non-irrigating households. These descriptive analyses help to frame the econometric results obtained in the study.

3.1.1. Household Characteristics

Household members are the major sources of labour for agricultural practices in agrarian societies. The household characteristics such as age, size of family, education level and etc. differ from one household to the others. The details of these characteristics for the sampled households in the study area are depicted in tables 1.

Table 1. *Family size, number of family involved on Agri-activiteis and Dependency ratio of irrigation user and non-user households.*

Characteristic	Irrigation User (N=64)			Non user Irrigation (N=64)			Total household (N=128)			t-value for difference
	Min	Max	Av	Min	Max	Av	Min	Max	Av	
Family size	1	12	4.9	1	13	5.6	1	13	5.2	2.4**
Number of family members involved on Agri-activiteis	1	8	3.9	1	10	4	1	10	3.9	3.7***
Dependency ratio	1	5	1.6	1	6	0.8	1	6	1.2	1.1

***, ** indicate significant at the 1% and 5% significance levels, respectively

Family size is useful for formulating various development plans and for monitoring and evaluating their implementation. Average family size at the national level in Ethiopia was 4.7 [9]. Table 1 reveals that, the minimum, maximum average and t-value of the sampled household of irrigation user non-user are depicted in this table. In the study area, the average family size was 5.2 with a minimum 1 and maximum of 13. The t-test shows that there is significant difference in family size between the irrigating and non-irrigating households at a 5% level of significance.

In rural Ethiopia, number of family members involved on Agri-activiteis is the main source of labor for all income sources. Family size in adult equivalents indicates the sample households‟ average family labor force for agricultural production and other income-generating activities.

The number of family members who engaged in agricultural activities differs from household to household of the study area. Accordingly, the number of family members engaging in agricultural activities in the study area was 3.9,1 and 10 are indicate average, minimum and maximum of user and non-user irrigation respectively. The t-test shows that there is significant difference between irrigating and non-irrigating households at 1% level of significant (Table 1). Thus, irrigating households have owned better labor input than non irrigating households.

The dependency ratio shows the ratio of economically inactive compared to economically active. Economically active members of a household, whose age is from 15 to 64, are assumed to be the principal sources of income for the household. Household members under 15 and over 65 are assumed to be economically inactive and dependent on economically active members of a household [22]. Members of holdings with high dependency ratios might not be able to participate in programs and projects due to time, labor and/or financial constraints, that is, dependency ratio is thought to be negatively related to income of households [14]. In the study area, accordingly the number of family members engaging in agricultural activities in the study area was 1.2,1 and 6 are indicate average, minimum and maximum of user and non-user irrigation respectively. The t-test shows that there is statistically insignificant difference between irrigating and non-irrigating households (Table 1).

Table 2. *Sex, gender and education of the household head.*

Characteristic	Irrigation User (N=64)	Non user Irrigation (N=64)	Total household (N=128)	Chi-square test for difference (χ^2)
	Percent	Percent	Percent	
Household Head gender				
Male	90.5	84	87.25	
Female	9.5	16	12.75	
Total	100	100	100	4.4**
Household Head Education				
Illiterate	24	65	44.5	
Read and write	48	24	36	
Elementary complete	27	11	19	
High school and above	1	0	0.5	
Total	100	100	100	24.7***
Age of household head				
15-30 years	17	14	16	
31-45 years	53	47	50	
46-64 years	28	34	31	
65 and above	2	5	3	
Total	100	100	100	1.9

***, ** indicate significant at the 1% and 5% significance levels, respectively.

In the study area, the head of the household generally is responsible for the coordination of the household activities. As such it is pertinent to examine attributes such as sex and education of the head as one component of irrigation participation decisions. Of the 128 sampled households, about 87.25% were male-headed. The percentage of non-irrigating female household heads was more than irrigating (Table 2). There is a significant difference in the sex of the sampled household heads for irrigating and non-irrigating households at a 5% significance level (Table 2).

Educated people can more easily contribute to the generation of new technologies and more readily utilize those technologies. It is one of the main factors affecting adoption of irrigation technologies to improve agricultural productivity [22]. The education level of household heads is higher for irrigating households than non-irrigating households (Table 2).

The average age of the household heads in the study area was 45 years with a minimum of 25 and maximum of 81 years. The age of the household head influences whether the household benefits from the experience of an older person, or has to base its decisions on the risk-taking attitude of a younger farmer. There is no significant difference in the distribution of household head age of the sampled households between irrigating and non-irrigating household heads (Table 2).

3.1.2. Wealth Characteristic

In agricultural production wealth of land holding, Livestock, agricultural tools and other capital assets are the most important. Therefore, the study looks the access of wealth characteristic of land holding, cultivated land and Livestock between irrigating and non-irrigating households.

Table 3. *Average Land holding, Cultivated land and Livestock (TLU).*

Characteristic	Irrigation User (N=64)	Non user Irrigation (N=64)	Total household (N=128)	t-value for difference
Land holding	1.45	1.2	1.35	1.90
Cultivated land	1.2	0.75	0.98	6.45***
Livestock (TLU)	4.9	3.5	4.2	4.7***

***, ** indicate significant at the 1% and 5% significance levels, respectively.

Land is the major productive asset in agrarian countries like Ethiopia. The average land holding size of the sample households in the study area is 1.35ha. There is no significant difference between irrigating and non-irrigating households in average land holding size (Table 3).

However, there is a significant difference in their cultivated land size. Irrigating households have larger cultivated land area than non-irrigating households. Irrigation may generate income and allow accumulation of other productive assets by irrigating households, which facilitate cultivation of additional land through share in and rent in from non-irrigating households. There is a significant difference between irrigating and non-irrigating households at the 1% significance level (Table 3).

Livestock are the most important productive assets in the household. In the study area, livestock are important source of power for ploughing, transportation, and riding. It also considered as a saved asset used during periods of food shortage. The average livestock holding for sample households was 4.2 TLU. Irrigating households possess a larger average number of livestock (4.90) than non-irrigating households (3.5). There is a significant difference between irrigating and non-irrigating households at the 1% significance level (Table 3).

3.2. The Models Results

This section presents the levels of technical efficiency and examines the variation in technical efficiency of irrigation user and irrigation non-user sample households. Desta Fayera, described clearly the purpose of efficiency measurement in his works [11].

To measure the existence of efficiency differential among the sampled rural households of both groups, the Cob-Douglas production function was estimated using the FRONTIER Computer Program Version 4.1 [8]. In determining the explanatory power of the fitted model the coefficient of determination (R^2) was calculated and tested. The calculated R^2 value was found to be 0.76, which implies that the fitted model has got good explanatory power. Therefore, it can be concluded that the fitted model has got high explanatory power. Therefore, the Cobb-Douglas production function model was found to be sufficient to estimate the input variable as well as the inefficiency parameters.

The combined result of the OLS and ML estimation of the production function of the irrigation user households and non-user households. The purpose of this estimation is that, technical inefficiency is measured in terms of the deviations of each firm's output from the maximum attainable output. Hence, each firm's output is measured against the fitted regression line. Moreover, the regression lines fitted for the two groups of sampled households are different and comparison of inefficiency of households belonging to different group with different regression line or reference point is extremely difficult and misleading. Therefore, the combined result of the OLS and ML estimation of the production function for the two groups is presented to indicate, how much each groups are efficient or inefficient compared to the overall mean technical efficiency value. The results of the efficiency estimates using frontier production function analysis for the sample households of the two groups are presented in Table 4.

Table 4. *OLS Estimation for technical efficiency of user and non-user of household irrigation farm production.*

Variables	Parameters	Estimated value Irrigation users		Estimated value Irrigation non-users	
		Coef.	t-value	Coef.	t-value
Constant	α_0	5.63	6.120 ***	5.800 ***	6.420***
Ln land	β_1	0.597	3.942**	0.428**	3.100***
Ln labour man-days	β_2	0.049	0.480	-0.32	-1.120
Ln input use (in birr)	β_3	0.642	8.523***	0.420 ***	7.130***
Ln oxen-days	β_4	-0.092	-0.742	0.426**	3.572**
Log-likelihood function		2.572	2.903	7.204	10.360
$\delta^2 = \delta^2_u + \delta^2_v$		0.064	0.120**	0.073	3.995**
$\gamma = \delta^2_u / \delta^2_u + \delta^2_v$		0.724	1.73 *	1.32	15.043
Mean efficiency		0.89		0.70	
Number of households		64		64	

Note: Figure in parantheses are t-ratios
*,**,***, indicates 10%, 5% and 1% significance level

Although, it is of less importance for comparison of the level of technical efficiency of the two groups of households, some useful generalizations can be derived from the model output depicted in Table 4. The maximum likelihood estimates of the variables included in the model showed varying degrees of relative importance between the groups. As indicated in Table 4, despite the fact that the estimated coefficient of land is significant in irrigation user and non-user households, the level of significance was 5 percent and 1-percent for irrigation non-user and irrigation user households respectively. Moreover, the estimated coefficients of the input variable land were found to be 0.620 and 0.324 for irrigation user and irrigation non-user households respectively, indicating the greater marginal contribution of land to agricultural output when irrigation technology is in place.

Furthermore, the estimated coefficients of capital were 0.642 and 0.420 for irrigation user and irrigation non-user households respectively and significant at 5 percent and 1 percent significance level respectively. However, the coefficient of capital for irrigation user households is greater than the input's coefficient for non-user households implying that the marginal productivity of capital is larger for irrigation users than marginal productivity of capital for irrigation non-users. Therefore, it can be observed that the use of irrigation has improved the marginal productivity of other variable inputs to agricultural output and hence increased the efficient utilization of land and capital.

The coefficient of labour was 0.049 and -0.32 for irrigation user and irrigation non-user households respectively and found to be insignificant in both cases. In contrast, the coefficient of oxen-days utilized is larger (2.315) and significant for irrigation non-user households than its coefficient (-0.092) for irrigation user households, indicating the relative importance of animal power for rain-fed agriculture. With respect to the inefficiency measurement in both groups, the gamma value for irrigation non-user households is higher than the value for irrigation user households Table 4. The mean values of gamma for irrigation user households and irrigation nonuser households are 0.724 and 1.320 respectively.

Moreover, the value of the t-value (15.043) observed for the estimated gamma of irrigation non- user households were found to be highly significant at 1 percent significance level.

In contrast, the value of the t-value (1.73) observed for the estimated gamma of the irrigation user households was found to be significant at 10 percent significance levels. Furthermore, the mean technical efficiencies of irrigation user households and irrigation non-user households were 89 percent and 70 percent respectively. Hence, it can be observed from the model output depicted in Table 4 that the use of irrigation has got significant impact on the technical efficiency improvement of farming households. Moreover, there can be a potential for efficiency improvement within irrigation user and irrigation non-user households.

Table 5. *OLS estimation of the production function and inefficiency for combined irrigation user and non-user households.*

Variables	Parameters	OLS Estimated value for user and non user		MLE Estimated value for user and non user	
		Coefficient	t-value	Coefficient	t-value
Consant	α_0	5.446	7.360***	4.765	11.95***
Ln land holding (ha)	β_1	0.960	4.750***	0.547	3.940**
Ln labour (man-days)	β_2	0.234	1.968	-0.091	-0.657
Ln capital (value of input in birr)	β_3	0.749	12.960***	0.575	13.306***
Ln oxen-days	β_4	0.055	0.596	0.094	0.899
Inefficiency effects					
Intercept	δ_0	-0.242		-0.956	
Age of household head	δ_1	0.074		1.743	
Land holding	δ_2	0.089		0.997	
Distance from Development center (in hours)	δ_3	-0.045		-1.861*	
Participation in extension Package program	δ_4	0.094		0.780	
Access to irrigation technology	δ_5	0.366		2.95**	
Sigma square	δ^2	0.093		0.07	5.655***
Gamma	γ	0.320		0.793	
Log-likelihood function		-11.36		7.95	
Mean efficiency		0.795			
Number of households		128		128	

Note: Figures in parentheses are t-ratios
*, **, *** indicates significant at 10%, 5% and 1% significant level respectively

Table 5 shows the Maximum Likelihood Estimates of parameter of stochastic production frontier. For the purpose of comparison, the OLS estimates of the parameters have also been presented. Among the variables included in the production frontier, the parameter estimates of landholding of the household and capital (includes, improved or local seed, fertilizer and chemicals) were found to be significant.

The other two variables, human labour and oxen power were turned out to be insignificant. Given household landholding and cropping intensity of the study area, the possible reasons for the parameters to be insignificant could be the labour congestion, a situation in which larger amount of labour perform relatively lesser amount of agricultural activity. It could also be because of the restrictive condition of the Cobb-Douglas specification of the model. The coefficients of the parameter estimates of capital, household landholding, oxen power and human labour are 0.575, 0.547, 0.072, 0.094 and -0.091 respectively. This indicates that there is variability in relative importance of these inputs for agricultural productivity.

In Cobb Douglas production function, the parameter coefficients measure the elasticity of production which, imply that keeping other variables constant, a one percent increase in capital input shall lead to an increase of 0.575 percent in agricultural output. Given the current prevailing conditions in the study area, the marginal productivity of capital, keeping all other factors constant, is the highest followed by the size of household landholding. These inputs are the most important inputs among the others. More importantly, the bigger marginal productivity of capital with respect to agricultural output reflects the greater need of capital by rural households. With regards to efficiency measurement, the maximum likelihood estimates of Cobb Douglas stochastic frontier production function coefficients were used to predict the technical efficiencies of individual farmers. The signs of most of the estimates of the inefficiency parameters are as expected in a priori hypothesis. However, the sign of the estimate of the distance between the farmers' residence and development centers was found to be negative. This implies that the higher the distance from development center the higher the efficiency of the farmer. Although unusual, such result may be expected when extension agents do not have technologies to offer or offer technologies for competing enterprise. Furthermore, the extension package program underway was started before twelve years and at the initial stage the participants were farmers closest to the development centers. As the activity advanced, farmers in the program started graduating after two years of participation in any one or more of the components of the program. Then the new entrants would come in to the program and this process continued from the center towards the periphery.

Therefore, farmers towards the periphery are those who have recently participated or are currently receiving new technologies and technical advice and can be more efficient as compared to farmers located close to the center. Access to irrigation has a significant and positive influence on the improvement of technical efficiency of farming households. In other words, having no access to irrigation contributed to inefficiency of the farmer. Moreover, the estimated gamma value is very low and insignificant indicating that the variability in production among household is much affected by measurement error than the inefficiency effects (the value is indicated in Table 5). The frequency distributions of technical efficiency of the individual sampled farmer in the study area are presented in table 5. The technical efficiency ranged from 71 to 97 percent for irrigation users and from 53 to 87.6 percent for irrigation non-users. The mean technical efficiency for the whole sample is 79.5 percent. In comparison with the findings of [3], the mean technical efficiency obtained in this study is much higher. The finding of the study is in conformity with the finding of [11], which obtained the mean technical efficiency of 78% for impact of community managed on farm production and 77% for irrigated potato farms under modern irrigation schemes respectively.

Table 6. *Distribution of households by technical efficiency ranges.*

Technical Efficiency ranges	Irrigation user households No	Percent	Cumulative percent	Non-user irrigation households No	Percent	Cumulative percent
<0.5						
0.5-0.6				12	18.75	18.75
0.6-0.7				28	43.75	62.5
0.7-0.795	6	9.52	9.52	17	26.5	81.25
0.795-0.9	41	65.1	74.6	7	12.07	100
0.9-1.0	16	25.39	100		-	
Total	63	100		64	100	

18.75 percent of irrigation non-user households have got technical efficiency of less than 60 percent. Moreover, 87.5 percent of irrigation non-user households perform at less than average technical efficiency level of 79.5 percent and only 12.5 percent of these households perform in the range of 79.5-87.6 percent technical efficiency. None of the irrigation non-user households have got technical efficiency greater than 87.6 percent. Hence, for irrigation non-user households; there exist considerably high inefficiencies (15 - 45%) and technical efficiency deviations from the average technical efficiency score and from the frontier in general. On the other hands, only 9.5 percent of irrigation user households have got technical efficiency less than average and about 90.5 percent performed above the average technical efficiency level. In general, 40.2 percent of sampled households (both irrigation user and non-user households) have got an efficiency level of less than average, 37.7 percent of households range between 79.5-90 percent efficiency and only 12.6 percent of households have got efficiency between 90 and 96 percent.

4. Conclusions and Recommendations

4.1. Conclusions

Based on the above findings of the study, the following implications or concluding remarks can be drawn for further consideration and improvement of irrigation development in the region in particular and in the country at large.

This study indicated that there is a considerable potential for increasing the technical efficiency of the farmers using the current levels of agricultural inputs and production technology. Specifically the result suggests that at the given level of fixed and variable inputs and farming practices, output could be increased by 20.5 percent if less efficient farmers were pushed to the level of efficiency achieved by the best farmers. The results clearly show that there are technical efficiency differences across households and, consequently there is possibility to increase output without major increase in the inputs and technological change. To bring about sustainable agricultural productivity, besides supplying agricultural inputs, factors that influence the efficient use of these inputs should be identified and considered. The technical efficiency estimate of participation in the extension package program was found to be insignificant. The result has deviated from our initial hypothesis and as well as the government's expectation regarding the outcome of the program. This might be because the extension package program currently underway is losing its momentum and (or) the technologies the program comprises have exhausted. Hence, this result calls for the critical evaluation and reformulation of the existing extension package program so as to improve the productivity of agricultural input variables and ensure the attainment of food security in the country.

Furthermore, during the study some of the costs for irrigation development activities were not available (was not possible to get) and hence, the comparative of irrigation was considered only form the point of view of households' efficiency improvement. Therefore, further research that take into consideration costs and examine the profitability aspect of irrigation development should be conducted.

4.2. Recommendations

Productivity is significantly higher on farms having access to more reliable irrigation system, as compared to the non-irrigated farms and the farms relying only on a single relatively less ensured source of irrigation. The results of efficiency analysis show that the average technical efficiency is about 79.5 percent and thus an average farmer is producing 20.5percent less than the achievable potential output.

Input use was found to be significant for both irrigation user and non user to improving productivity. This implies that the current level of use of input has to be increased through different policy initiatives. Farmers have to be provided with easy and affordable credit service, extension advice has to be strengthened to households; field demonstrations on advantages of improved input use and management could be considered as an important strategy in creating awareness, continuous training and follow up on the application of improved input use and management. There have been initiatives by the government to train farmers on the use of agricultural inputs and capacitating the existing farmers' training centers and expanding their coverage as well as strengthening the field level training programs are highly demanded to improve productivity.

The use of oxen power in farm operations such as land preparation and sowing was highly significant in influencing productivity. In other words, oxen power augments labor input and enhances its productivity by reducing the time and drudgery needed to accomplish farm operations such as land preparation and sowing. However, the ox holding of farmers in the study areas was found to be miserable. As a result, initiatives that improve oxen holding of farmers such as targeted credit and improved animal health service have to be looked for. Again, initiatives that enhance the traction power of the existing oxen such as improved feeding and management practices as well as improved farm implements have to be introduced to attain gains in productivity.

Abbreviations and Acronyms

AfDF: African Development Fund
CSA: Central Statistical Agency
DA: Development Agent
EARO: Ethiopian Agricultural Research Organization
FAO: Food and Agriculture Organization
FDRE: Federal Democratic Republic of Ethiopia
HHs: Households
IMT: Irrigation Management Transfer
IWMI: International Water Management Institute
JICA: Japan International Cooperation Agency
Mha: Million hectares
MOA: Ministry of Agriculture
MOFED: Ministry of Finance and Economic Development
MNRDEP: Ministry of Natural Resources Development and Environmental Projection
MoWR: Ministry of Water Resources
NGO: Non-Government Organization
OLS: Ordinary Least Squares
KM: Kilometer
RWH: Rain Water Harvesting
SPSS: Statistical Package for Social Scientists

Ethical

This study follows all ethical practices during writing.

Transparency

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study was reported; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Conflicts of Interest

The authors declare that they have no conflict of interests.

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