

Analysis of Levels and Determinants of Technical Efficiency of *Tef* Producers in Walmara District, Ethiopia

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Abstract: Agriculture is the backbone of the Ethiopian economy on which 80% of Ethiopians base their livelihoods. Technical efficiency is the level to which the maximum possible output is achieved from a given combination of agricultural production inputs. This study aimed to analyze the level of technical efficiency and identify sources of inefficiency among *tef* cultivating farmers in Walmara district, Ethiopia. The study was conducted based on primary data collected from 261 sample households. For the analysis of collected data, both descriptive statistics and econometric models were used. A Cobb-Douglas stochastic frontier production model was used to estimate the technical efficiency score and identify the determinants of efficiency levels. The MLE of the stochastic frontier production model indicated that *tef* output was statistically significantly and positively affected by three production inputs including oxen, fertilizers, and herbicides. The mean technical efficiency of sampled households in the district was 83.3% which indicates the respondents have the potential to raise *tef* output by about 16.7% by using available production inputs on hand efficiently. The estimated results of the inefficiency model presented that the sex of household heads, educational level, and livestock owned affect the technical inefficiency of *tef* producers negatively and significantly. The model result specifies that being a male household head, attending formal education and the number of livestock make *tef* producers technically efficient to produce more. Hence, the agricultural sector policies and strategies that improve the skill of farmers and the provision of agricultural production inputs timely and in adequate quantity make *tef* producer farmers more productive and efficient.

Keywords: *Tef*, Technical Efficiency, Stochastic Frontier Production, Walmara

1. Introduction

The agricultural sector is the mainstay of the Ethiopian economy on which 80% of Ethiopians base their livelihoods. Agricultural production technology generation and dissemination through research and development lead to enhance agricultural production and total factor productivity. Technical efficiency is explained as the extent to which the maximum possible output is achieved from a given combination of available agricultural production inputs. Any deviation from the maximum conceivable output is typically considered a technical inefficiency [1]. *Tef* production contributed 5.5 million tons of output and was cultivated by 6.9 million households in Ethiopia. Whereas *tef* contributed

2.7 million tons of outputs Oromia region and cultivated by 2.8 million holders. The average national productivity of *tef* was 1.88 tons/hectare and the regional average was 1.93 tons/ha [2]. Crop yield can be increased through the development of production technology and adoption of these improved production technologies or through enhancing the technical efficiency of farmers [3]. In agriculture, the actual yield is explained as the yield attained in a farmer's field in a given production period. To represent variation in time and space in a defined geographical location, it is defined as the average yield (in space and time) achieved by farmers in the areas under the most widely used management practices (sowing date, row planting, cultivar, maturity date, and plant density, nutrient management, and crop protection). Whereas attainable yield is the best yield achieved through skillful use of the best

agricultural production technology. Some studies use attainable yield as an approximation to either potential yield or water-limited yield [4].

The yield gap is estimated by subtracting the achieved average yield from the yield potential [5]. The existence of inefficiency reveals that output can be increased without requiring additional production inputs and new production technologies by utilizing existing production resources efficiently [6]. Thus, the analysis of TE has significance where agricultural production resources are scarce. The introduction of improved agricultural production technology alone couldn't bring the expected shift of the production frontier. Even if improved agricultural technologies are available there is still a gap in the level of production and productivity under farmer's management. To generate essential information on the level of technical efficiency and determinant of technical inefficiency of *tef* cultivating farmers in the study areas, this study is essential to fill the information gap and to take improvement measures.

2. Research Methodology

2.1. The Study Area

The location for this study was Walmara district of Finfinnee surrounding the Oromia special zone, Ethiopia. Walmara district is among the eight districts of Finfinnee

surrounding Oromia special zones. The district is located 30 km away from Addis Ababa, in the west direction along the main road to Ambo. The geographical location of the district is situated within 08°50'15" N latitude and 038°25'45" E longitude. Walmara district is bordered by Ejere district on the west, Ada Barga district on the northwest, Sebeta Hawas on the east, and Burayu town on the north. According to the census report of CSA [7], the total population of Walmara district was 83,823 (42,115 males and 41,708 females). Concerning the population projection report of CSA [8], the population of Walmara district was 112,498 (56,200 were male and the rest 56,298 were females).

The total area of Walmara district is 65,605 hectares and is classified into highland and midland agroecology. The majority parts (61 percent) of the districts are highland, and the rest 39 percent are midland; with an altitude ranging from 2060 to 3380 meters above sea level. The mean altitude of the district is 2400 meters above sea level. The annual rainfall of the district varies from 795mm to 1300mm, and its average annual rainfall is 1144 mm. The annual temperature of the district ranges from 6°C to 24°C, and the average annual temperature is 14°C. There are 23 rural Kebele administrations and three towns. The district is characterized by a crop and livestock mixed farming system. The major crops grown in the main season are wheat, barley, *tef*, pulses, oilseeds, and potatoes.

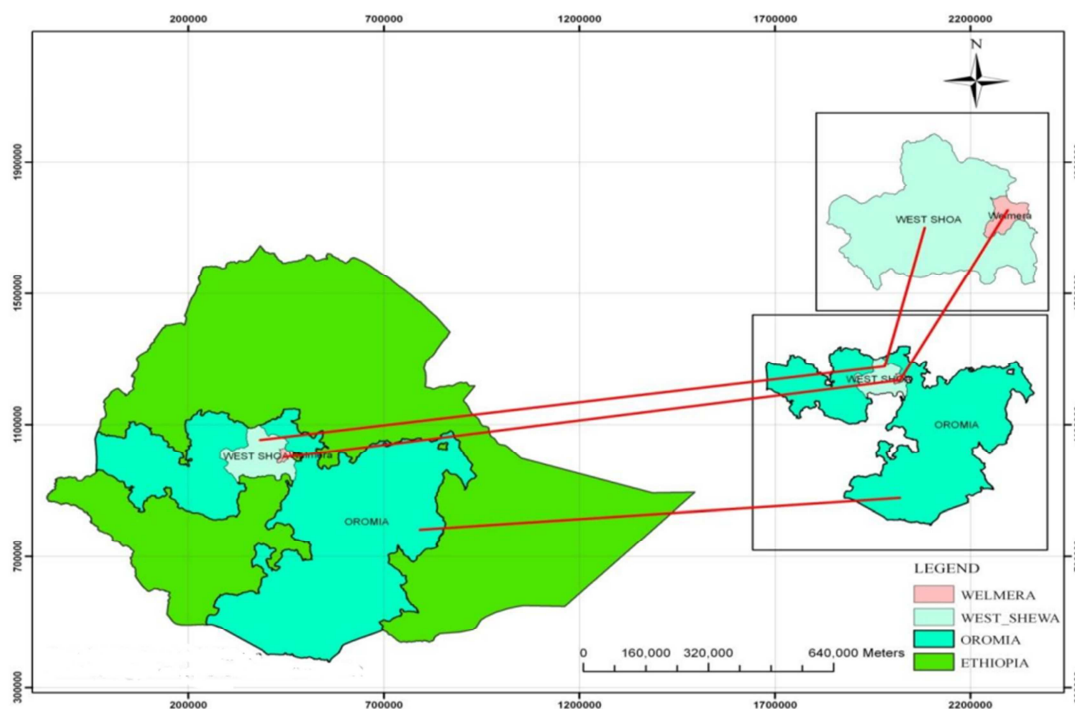


Figure 1. Location of the study area, source: adapted from [9].

2.2. Data Types, Sources, and Methods of Data Collection

In this study, both primary and secondary data were used employed. Primary data were collected from randomly selected *tef* producers in four rural kebeles in the district. The

primary data collected were by focusing on demographic characteristics of the sample household, farming experience, livestock owned (TLU), distance to the nearest market, access to credit service, and production inputs used in *tef* production. Primary data were collected by structured and semi-structured

questionnaires. Secondary data were taken by reviewing secondary sources from published and unpublished documents and journals were visited focusing on the aim of the study.

2.3. Sampling Procedure and Sample Size Determination

The target populations for this study are *tef* producer farmers in Walmara district. A purposive and two-stage random sampling procedure was used for the selection of sample household heads. Walmara district was selected purposively. In the first stage, four *tef* producing kebeles were selected from *tef* producing kebeles of the district. In the second stage, 261 sample respondents were selected randomly using probability proportionate to the size of *tef* producer households from the total households in the selected four kebeles. The total sample size ($n=261$) was determined following a simplified formula provided by Yemane [10]. Accordingly, the required sample size of 95% confidence level with a degree of variability of 5% and a level of precision equal to 7 was used to obtain the sample size required.

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

Where: n = sample size, N = population size (sampling frame) and e = level of precision.

2.4. Methods of Data Analysis

Both descriptive statistics tools and econometric models were employed in analyzing the data collected from sample *tef* producers.

2.4.1. Descriptive Statistical Analysis

Descriptive statistical tools such as mean, proportions, percentages, standard deviations, and graphs were used in describing farm households' demographic and socio-economic characteristics, and farm input was used.

2.4.2. Econometric Analysis

The stochastic frontier production (SFP) econometric model was used to identify factors affecting of technical

efficiency of *tef* producing farmers. Parametric Stochastic Frontier Production (SFP) econometric model developed by Aigner, Lovell, and Schmidt [11] was used to analyze production inefficiency. The relationship between the *tef* output (Y_i) and the inputs used (X_i) is represented through the production function $f(\cdot)$ as follows,

$$\ln Y_i = \beta_0 + \sum_{n=1}^N \beta_n \ln X_{ni} + \varepsilon_i(V_i - U_i) \quad (2)$$

Where: \ln signifies the natural logarithm, Y_i is the *tef* output of a given farmer i ; β is a vector of parameters to be estimated; X_i is the vector of input quantities expected to affect production function; ε_i is error term equals to $(V_i - U_i)$; V_i represents the independently and identically distributed $N(0, \sigma^2)$ random errors terms. It is randomly distributed in the cultivation process that cannot be influenced by the farmer and is independent of U_i ; U_i represents non-negative random variables associated with technical inefficiency in production, independently and identically distributed as half-normal with mean μ , $\mu \sim (N^+(\mu, \sigma_u^2))$. Battese and Coelli [12] indicated the maximum likelihood (ML) estimation of Eq. (2) yields estimators for β and γ ;

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad (3)$$

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \quad (4)$$

Where; σ^2 is the variance parameter that denotes the total deviation from the frontier; the γ parameter has a value between 0 and 1. A zero value of γ indicates that the deviations from the frontier are due entirely to noise, while a value of 1 would indicate that all deviations are due to technical inefficiency. σ_u^2 is the variance parameter that denotes deviation from the frontier due to inefficiency; σ_v^2 is the variance parameter that denotes deviation from the frontier due to noise. The dependent variable in the SFP model is *tef* output and the hypothesized agricultural inputs used variables in *tef* production include seed, labor, oxen plowing, fertilizers, herbicides, and areas allocated for *tef* (Table 1).

Table 1. Hypothesized explanatory variables used in the study.

Input variables for estimating technical efficiency			Hypothesized variables for determinants of technical inefficiency		
Variables	Measured	Expected effect	Variables	Measured	Expected effect
lnQp	Kg		Sex of hh	Dummy: male=1; otherwise= 0	-
lnSeed	Kg	+	Household size	Man equivalent	-
lnLabour	Man-days	+	Education level	Years of schooling	-
lnOxen	Oxen-days	+	Farming experience	No of years	-
lnFertil	Kg	+	Livestock owned	TLU	-
lnHerb	litter	+	Access to credit	Dummy: if used=1; if not= 0	-
lnArea	Hectare	+	Distance to market	Kilometers	+

Source: Reviewed from emphatical literature.

The technical efficiency (TE_i) of the i^{th} farmer given the levels of inputs used in *tef* production is defined by equation 5,

$$TE_i = \frac{Y_i}{f(X_i; \beta) \exp(V_i)} = \exp(-U_i) \quad (5)$$

The technical efficiency of the sample respondent is between 0 and 1 and is inversely related to the level of the technical inefficiency effect. Technical inefficiency effect (U_i) with mean μ_i is defined as,

$$U_i = \alpha_0 + \alpha_1 L_i \dots + \alpha_n L_n + Z_i \quad (6)$$

Where L_i is the characteristics of the farmer; the α_0 and

α_i coefficients are unknown parameters to be estimated along with the variance parameters σ^2 and γ , and Z_i is the error term.

The estimated technical inefficiency scores are used as the dependent variable in the inefficiency model. The explanatory variables proposed to determine the inefficiency of *tef* producers are (Sex of household head, household size, education level, farming experience, livestock owned, access to credit, and distance to the nearest market (Table 1). The SFP and inefficiency functions (equations 2 & 6) can be estimated in a one or two-step procedure. As shown in Wang and Schmidt's [13] two-step estimation procedures results in biased coefficients. In this study, a one-step estimation procedure was used.

3. Results and Discussions

3.1. Descriptive Statistics Results

3.1.1. Characteristics of Sample Respondents

As shown in Table 2, out of the total sample households 228 (87.4%) were male-headed respondents and 33 (12.6%) were female-headed households. Concerning credit service, 242 (92.7%) of the sample households have access to credit service and 19 (7.3%) haven't credit service in the study areas.

Table 2. Distribution of sample respondents by sex and access to credit.

Variables	n	%
Sex of household head		
Female	33	12.6
Male	228	87.4
Access to credit		
Yes	242	92.7
No	19	7.3

Source: Own survey result.

The output in Table 3 specifies that the average household size of sample respondents in the study areas is 4.53 adults equivalent with a standard deviation of 2.22. Concerning the educational level of sample household heads, the average number of schooling completed was 5.3 years with a standard deviation of 4.12. The average years of farming experience of sample households engaged in *tef* production were 10.19 with a standard deviation of 8.8.

Table 3. Demographic and socio-economic characteristics of respondents.

Variables	Mean	Std. Dev.
Household size	4.536	2.223
Education level	5.326	4.126
Farming experience	10.192	8.801
Livestock owned	7.152	3.834
Distance to market	5.753	4.006

Source: Own computation.

Livestock resources serve as means of income to purchase agricultural production inputs and as a draft power for cultivating the farm. The mean livestock owned by sample respondents was 7.15 TLU with a standard deviation of 3.83, as shown in Table 3 above. The distance from the homestead to the nearest marketplace where farmers purchase production inputs and sold their produce was an average of

5.75 kilometers with standard deviations of 4.01.

3.1.2. Agricultural Inputs Used in *Tef* Production

The production inputs used in *tef* production were land, seed, labor, oxen, fertilizers, and herbicides. The production function for this study was estimated using six agricultural input variables. The survey result indicates that the average *tef* outputs produced are 10.12 qt with a standard deviation of 5.98, which is the dependent variable in the production function. The mean area of land allocated for *tef* cultivation by sample households is 1.06 ha with a standard deviation of 10.81 (Table 4). The average amount of *tef* seed used by sample households is 32.12 kg with a standard deviation of 3.55. The mean labor used per hectare was 56.59 man-days with a standard deviation of 36.62; the mean oxen draft power used for plowing per hectare was 26.94 oxen days with a standard deviation of 13.41. The average inorganic fertilizer used per hectare was 213.01 kg with a standard deviation of 239.54. Whereas the average amount of herbicides used for weed control is 0.98 liters with a standard deviation of 1.13.

Table 4. Major agricultural inputs used in *tef* production.

Variable	Mean	Std. Dev.
<i>Tef</i> produced (Qt/ha)	10.121	5.985
Area of <i>Tef</i> (ha)	1.06	10.817
<i>Tef</i> seed (kg/ha)	32.125	3.557
Labor (man-days/ha)	56.595	36.628
Oxen (oxen days/ha)	26.944	13.408
Fertilizers (kg/ha)	213.065	239.548
Herbicide (litter/ha)	0.98	1.135

Source: Own computation.

In the study areas, the majority of farmers plow more than two for cultivating *tef*. As shown in Figure 2 below, most of the farmers 140 (53.64%) plow their *tef* fields four times.

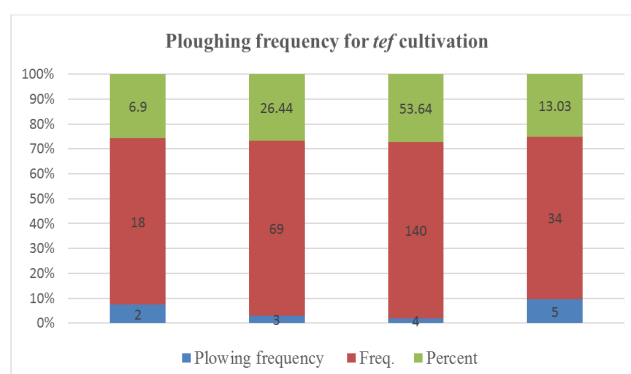


Figure 2. Ploughing frequency for *tef* cultivations. Source: Own computation.

3.2. Econometric Results

The MLE of the parameters used for stochastic frontier production functions and determinants of technical inefficiency is presented in Table 6 and Table 7, respectively.

3.2.1. Parameter Estimates of the SFP Model

The technical efficiency levels of sample households in *tef* cultivations were estimated using the stochastic frontier

production function (SFP). The agricultural input variables used in the SFP model were *tef* seed (kg), labor (man-days), oxen (oxen days), fertilizers (kg), herbicides (litter), and areas under *tef* cultivation (hectare). The result in the coefficients of the input variables is estimated under the full frontier production function (Table 5). Out of six input variables used in the production function, three of them (Oxen, fertilizers, and herbicides) had a significant effect in explaining the variation in *tef* output among *tef* producers. The model result shows the increased amount of oxen plow, fertilizers, and herbicide was found to positively and significantly affect *tef* production at a 1% significance level, respectively. This result showed that a unit increase of these variables enhances the amount of *tef* produced and its real. The result indicated that each unit increase in these inputs increases the level of *tef* output and this implies that there still exists a potential to increase *tef* output by increasing the use of production input. This result is supported by the findings [14, 15].

Table 5. Maximum Likelihood Estimate for Cobb-Douglas SFP.

Variables	Coefficient	Std.Err.	z-value
LnLabour	0.063	0.053	1.200
LnOxen	0.166***	0.061	2.730
LnSeed	0.336	0.231	1.450
LnFertilizer	0.218***	0.051	4.300
LnHerb	0.133***	0.037	3.580
LnArea	0.023	0.035	-0.650
Constant	-0.713	0.813	-0.880
Gamma(γ)	0.812***		
Lambda	0.404***		
Log-likelihood	-145.014		

Source: Own computation. *** indicates significance level at 1%.

Technical efficiency scores of sample respondents

In the results of Table 6, the efficiency scores of sample respondents specify the existence of a wide range of

variation in technical efficiency among *tef* producer farmers in the Walmara district. The efficiency scores indicate that the technical efficiency among the households ranges from 16.3% to 94.8%, with a standard deviation of 0.139. The average technical efficiency of sample households was 83.3%, which that shows on average *tef* producer households were acting below the maximum potential output by 17.7% and it is conceivable to increase *tef* output without using additional production inputs by employing available inputs efficiently.

The minimum technical efficiency score was 16.3% which infers the least performing farmer from sample respondents was operating 83.7% below the maximum output. The maximum TE is 94.8% showing that the best performer farmer was only 5.2% below the frontier production.

Table 6. Technical efficiency measures.

Descriptions	Efficiency scores
Mean	0.833
Std. Dev.	0.139
Min	0.163
Max	0.948
Skewness	-2.634
Kurtosis	10.539

Source: Own survey result.

As indicated in Figure 3 below the TE scores distribution showed that the majority of households 128 (49%) were technical efficiency scores greater than 90% even if there are some sample households whose technical efficiency levels were found below 50%. The result displays that *tef* producers in this category have room to improve their *tef* production at least by half in the study areas.

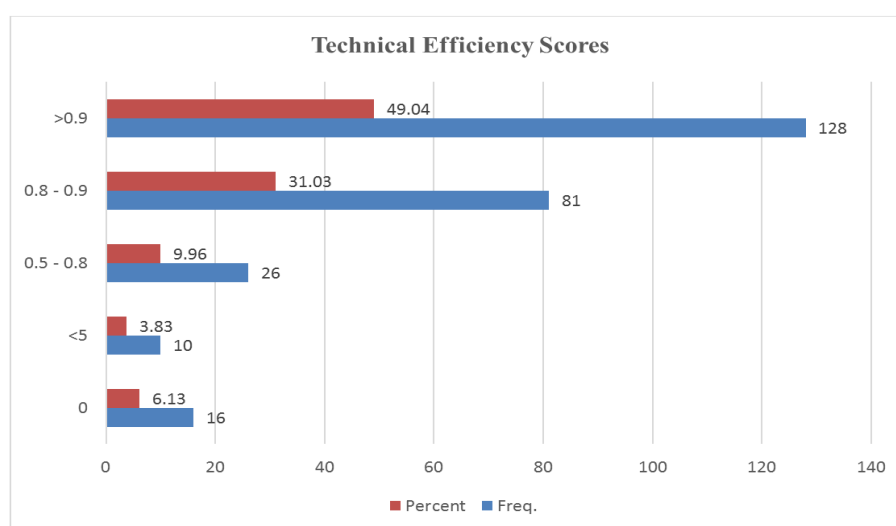


Figure 3. Distribution of *tef* producers' TE scores. Source: Own computation.

Actual and frontier level output

The variation between the actual and frontier level of *tef* output was analyzed by estimating the individual and the mean level of frontier output. Using the values of the actual

output gained and the predicted technical efficiency levels, the potential output was estimated for each sample farm household. Figure 4 below illustrates the presence of difference among sample households in observed and

potential *tef* output. The yield gap between the observed and potential output shows the opportunity to increase the

household level of *tef* output by eliminating the determinants of *tef* production and through improving farmers' TE.

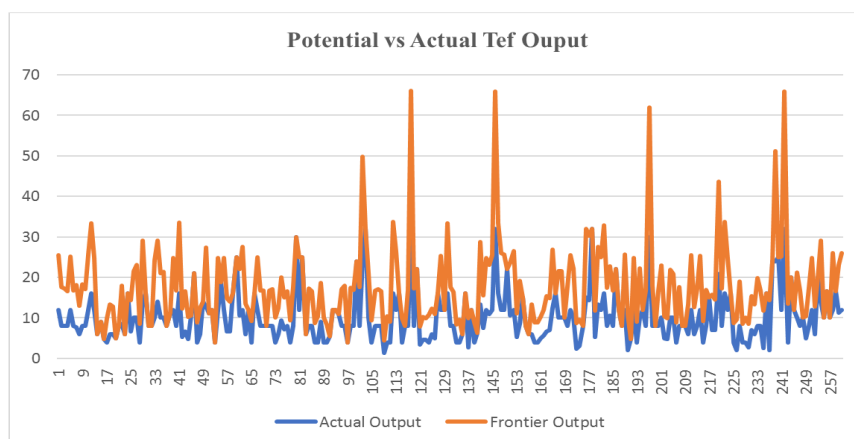


Figure 4. Distribution of *tef* producers' technical efficiency scores. Source: Own computation.

3.2.2. Determinants of the Technical Inefficiency of Tef Producers

The coefficients of *tef* production inefficiency variables included in the model were estimated using the estimated level of TE as a dependent variable. The explained variable of the inefficiency function represents the model of inefficiency, a negative sign on an estimated parameter revealed that the allied variable had a positive effect on efficiency. Table 7 below shows the determinants of technical inefficiency of *tef* production. The results from the SFP model indicated the three explanatory variables are statistically significant to affect the technical inefficiency of *tef* producers in Walmara district. The sex of the household head being male was found to negative effect on the technical inefficiency at a 5% significance level. This might be because male-headed households have the possibility of getting access to improved production technologies and training and are better in *tef* production than female-headed households. The result is due to the homestead activities falling upon the females. This postulates empowering female-headed households by proving continuous and practical training and delivering production inputs is essential to improve their technical efficiency.

As it was hypothesized educational status of the household head was found to have a negative and significant effect on the level of technical inefficiencies *tef* production at a 5% significance level. The result indicated that attending formal education improves the technical efficiency of farmers. The education level of household heads which can be a substitution variable for managerial ability, had a negative on technical inefficiencies of *tef* production inferring that educated farmers are more technically efficient than none educated farmers in adopting and managing production resources and enhancing *tef* productivity. Thus, improving access to formal education of *tef* producing farmers is required particularly in the study areas. This result is consistent with the findings of Moges *et al.* [16] that found educated farmers have the skill to capture information from

various sources and use technologies on their farm that would increase the outputs of *tef*.

Table 7. Factors affecting of technical inefficiency of *tef* producers.

Variables	Coefficient	Std.Err.	z-value
Sex of household head	-1.828**	0.732	-2.500
Household size	-0.086	0.158	-0.550
Education level	-0.201**	0.087	-2.300
Farming experience	-0.006	0.034	-0.170
Livestock owned	-0.366***	0.136	-2.700
Distance to the market	-0.059	0.082	-0.710
Access to credit	0.024	1.142	0.020
Constant	1.677	1.324	1.270

Source: Own computation. *** and ** indicates significance levels at 1% and 5%, respectively.

The number of livestock owned (TLU) was statically significant at 1% to affect the technical inefficiency of *tef* producer sample households negatively. This result is since having livestock resource are essential for the plowing of *tef* farm and solves the cash constraints to purchase production inputs like seed, fertilizers, and herbicides and this increases the technical efficiency level (Table 7). The result is supported by the findings of [17-18] who found that a unit increase in livestock owned increases the possibility of farmers being technically efficient and reduces the technical inefficiency of farmers.

4. Conclusions and Recommendations

Agriculture is the backbone of the Ethiopian economy on which 80% of Ethiopians base their livelihoods. This study aimed to measure the level of technical efficiency and identify sources of inefficiency among *tef* cultivating farmers in Walmara district, Ethiopia. The study was conducted based on the primary data obtained from 261 sample respondents. For the analysis, both descriptive statistics tools and econometric models were employed. A Cobb-Douglas SFP model with the inefficiency effect was employed

simultaneously to analyze the level of technical efficiency and identify the causes of technical inefficiency of *tef* producer farmers in a one-step ML estimation procedure.

The MLE of the stochastic frontier production model indicated that *tef* output was positively and significantly determined by three agricultural production inputs, including oxen, fertilizers, and herbicides in the study areas. The average technical efficiency of sampled households was 83.3% which indicates that the respondents have the potential to raise *tef* output by about 16.7% by using available inputs efficiently. The estimated results of the inefficiency model showed that the sex of household heads, educational level, and livestock owned negatively and significantly affect the technical inefficiency of *tef* producers. The negative coefficient of these explanatory variables to the technical inefficiency specifies being in a male-headed household, attending formal education and livestock owner make *tef* producers technically efficient. Thus, the focus should be given to enhancing the skill of farmers and availing appropriate agricultural production inputs timely and with the required quantity to make *tef* producers more productive and efficient.

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