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Technical Efficiency of Tef Producers: Evidence from West Shewa, Ethiopia

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Abstract
Tef (*Eragrostis tef*) is a major staple food crop and is important for generating farm income in Ethiopia and cultivated by more than 6.9 million farmers. The objectives of the study were to measure the level of technical efficiency and identify factors that cause efficiency differences among *tef* cultivating farmers in West Shewa, Ethiopia. The study was conducted based on the data obtained from 206 randomly selected households. For the analysis, both descriptive statistics and econometric models were used. A Cobb-Douglas stochastic frontier production model with the inefficiency effect was used to simultaneously estimate technical efficiency and identify the determinants of efficiency variations among *tef* producer farmers. The maximum likelihood estimates of stochastic frontier production showed that *tef* output was positively and significantly influenced by areas cultivated, and negatively affected by the increased seed rate and labour used. The estimated mean technical efficiency of sampled households in the study area was 84.3%, this shows that it is possible to raise *tef* output by about 15.7% without using additional inputs and by employing inputs on hand efficiently and there is a room to increase the output from the existing input combinations if farmers operate in an efficient manner. Livestock owned, use improved tef seed and proximity to the district market were found to negatively and significantly affect the technical inefficiency of *tef* producing farmers. Thus, stakeholders engaged in agriculture should emphasize on resources of farmers and the proximity to input and output market to improve the efficiency level of those less efficient farmers.
Keywords: Stochastic frontier analysis; Technical efficiency; *Tef*; West Shewa
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1. INTRODUCTION

In Ethiopia, *Tef* (*Eragrostis tef*) stands first in terms of land area coverage taking 2.9 million hectares which is 27.8 percent of areas out of cereal crop production. Ethiopia is the center of both origin and diversity for *tef* (Vavilov, 1951). *Tef* production contributed 5.5 million tons and was cultivated by 6.9 million households in Ethiopia and the average national productivity of *tef* was 1.88 tons/hectare. Agricultural productivity can be increased through the improvement in production technology by releasing improved and well-adopted crop varieties and other production inputs or through enhancing the technical efficiency of farmers in efficiently using and combining the available production inputs (Mechri, Lys and Cachia, 2017). In other words, productivity can be increased through the dissemination of improved technologies such as fertilizer and high-yielding varieties (HYV) and/or by improving the productive capacity of the farmer. Technical Efficiency (TE) is defined as the extent to which the maximum possible output is achieved from a given combination of available production inputs. Any deviation from the maximum output is typically considered as technical inefficiency (Coelli *et al.,* 2005).

In the Oromia region, *Tef* is cultivated by 2.8 million holders and covers 1.4 million hectares of land, and the land area coverage of *tef* in West Shewa zone is 201,734 hectares and cultivated by 368,488 households. In terms of production, *tef* contributed 2.7 million tons and 422,143 tons of production in Oromia and West Shewa zone, respectively (CSA, 2021). The productivity of tef in the zone (2.09 tons/ha) is higher than the national and regional average (1.93 tons/ha). However, in spite of the conducive natural environment, the inefficiency of the agricultural systems, and differences in the production efficiency of most farmers are hindering tef productivity (Knife et al., 2012). The existence of inefficiency means that output can be increased without requiring additional production inputs and new production technologies by utilizing existing production resources efficiently (Binam et al., 2004).

Hence, the measurement of TE has relevance for intervention where resources are insufficient and opportunities for developing and adopting better technologies are scarce. The introduction of improved agricultural technology and farmers' training alone couldn't bring the expected shift of production frontier at low efficiency level. Previously different studies were conducted on technical efficiency of cereal crops in different agro-ecology regions of Ethiopia. There is information gap on the level efficiency and technical inefficiency of tef cultivating farmers in the study areas. For this study, tef is selected because *tef* is grown by the majority of farmers. Hence, the study aims to measure the level of technical efficiency and identify the sources of inefficiency *tef* producers in the study areas.

2. RESEARCH METHODOLOGY

2.1 The Study Area

The study was conducted in West Shewa zone based at Dendi district, Ethiopia which is the potential area for *tef* production. The district is geographically situated within $038^{0}10'54''$E longitude and $9^{o}\ 01'16''$N latitude and at an altitude of 2200 meters above sea level. The total population of the district is 200715. Out of the total population, 42953(21.4%) are urban dwellers and 157762(78.6%) are rural dwellers. The total area coverage of the district is 79,936.29 hectares of which 39,227.5 hectares are cultivated land. The major cereal crops grown in the district includes: *tef*, wheat, barley, maize, and sorghum. The district has two agro-ecologies; highland (29%) and midland (71%) indicating the conducive environment the district has for *tef* cultivation. (DDAO, 2017).

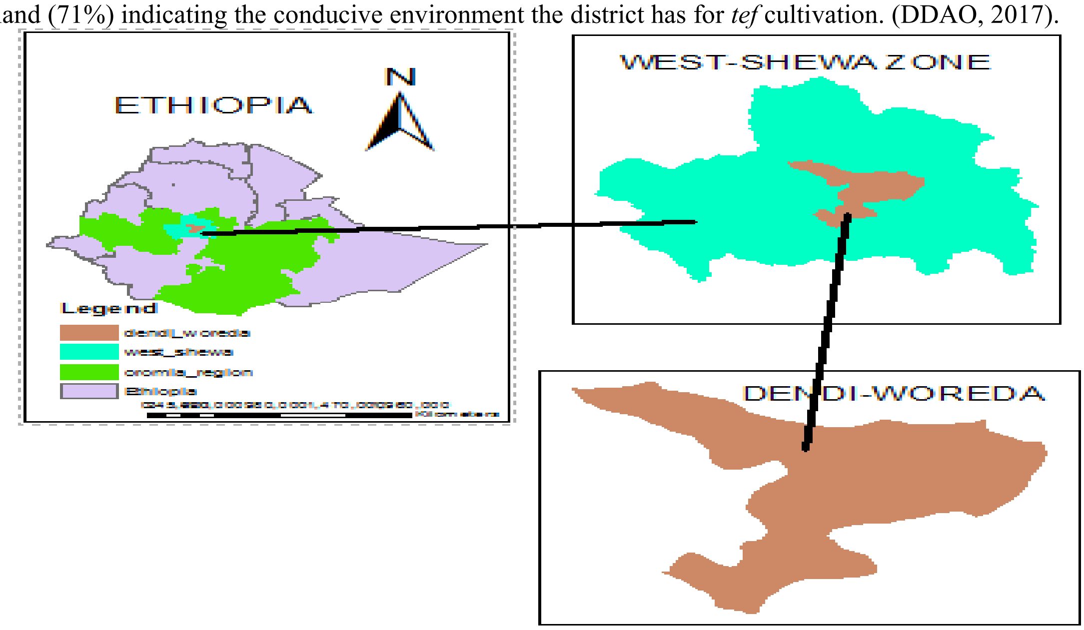

Figure 1. Location of the study area

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

For this study, both primary and secondary data types were used. Primary data were collected by structured and semi-structured questionnaires from randomly selected *tef* producer farmers. Secondary data from published and unpublished documents of Central Statistical Authority (CSA), agricultural and development office, journals, and websites were visited to generate secondary information.

2.3. Sampling Procedure and Sample Size Determination

To select sample respondents for this study, purposive and two stage random sampling procedure was used. From West Shewa zone, Dendi district is the potential area of *tef* production and selected purposively. Then, in the first stage, five *tef* producing kebeles were selected randomly from the total of *tef* producing kebeles. In the second stage, from a total of 2425 *tef* cultivating household heads, 206 sample respondents were selected randomly using pps following a simplified formula provided by Yamane (1967).

Table 1: Sample size of tef producer households in selected PA

Peasant Association	Total household's	Sample respondents selected
Dano Ejersa Gibe	618	53
Wamura Sako	585	43
Lokloka Abba	310	32
Werka Werabu	452	36
Yubdo Legabatu	460	42
Total	2425	206

Source: Own computation result

2.4. Methods of Data Analysis

Both descriptive statistics and econometric methods are used for data analysis. Descriptive statistical analysis methods (such as mean, proportions, percentages, and standard deviations) and Stochastic Frontier Production

(SFP) econometric model were used for the analysis.

Parametric Stochastic Frontier Production (SFP) econometric model developed by Aigner, Lovell, and Schmidt (1977) 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 (.) as follows,

$$\ln Y_i = \beta_0 + \sum_{n=i}^{N} \beta_n \ln X_{ni} + \varepsilon i(Vi - Ui) \quad (1)$$

Where, ln denotes 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 assumed to affect production function; $\mathcal{E}_i$ is error term equals to (V_i-U_i); V_i represents the independently and identically distributed N (0; σ^2) random errors terms. It is randomly distributed in the production 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, μ~ ($N^+(\mu, \sigma^2_u)$). Battese and Coelli (1988) indicated the maximum likelihood (ML) estimation of Eq. (1) yields estimators for β and γ;

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

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

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 SFP model is tef output and the hypothesized independent variables are production inputs including labor (man days); oxen ploughing (oxen days); fertilizers (kg); areas allocated for *tef* (ha) and *Tef* seed (kg). The technical efficiency of production (TE_i) of the i^{th} farmer given the levels of inputs is defined by equation 4,

$$TE_i = Y_i / f(X_i;\beta)\exp(V_i) = \exp(-U_i) \quad (4)$$

The technical efficiency of a farmer 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,

$$U_i = \alpha_o + \alpha_i L_i \ldots\ldots + \alpha_n L_h + Z_i \quad (5)$$

Where, L_i is the characteristics of the farmer; the α_o 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 technical inefficiency scores are taken as the dependent variable in the inefficiency model. Independent variables proposed to affect the inefficiency of *tef* producers are (Education level; Farming experience; Livestock owned; Use of improved *tef* seed; Total land owned; Number of plots; Access to Credit; Off/non-farm income; Distance to market and Extension service). The SFP and inefficiency functions (equations 1 & 5) can be estimated in one or two-step procedure. As indicated in Wang and Schmidt's (2002) two-step estimation procedures results in biased coefficients. Hence this study used a one-step estimation procedure.

3. RESULT AND DISCUSSIONS

3.1. Descriptive statistics results

3.1.1. Demographic and Socioeconomic Characteristics of Sample Households

The results from sample households educate that the educational level of sample household heads, the average number of formal schoolings completed was 4.15 years with a standard deviation of 3.61. The average years of farming experience of sample respondents that an individual continuously engaged in *tef* production was 18.4 with a standard deviation of 7.3 (Table 2). Mixed crop and livestock farming system is dominantly used in district by farm households. Livestock resources are an important source of cash for farmers' livelihoods and oxen are used as a draft power for crop production. The mean livestock owned by sample households was 4.2 TLU with a standard deviation of 2.3, as depicted in Table 2.

Table 2. General characteristics of sample households

Variables	Mean	Std. Dev.	Min	Max
Education level (years of formal schooling)	4.155	3.6	0	15
Farming experience (No of years)	18.417	7.376	4	37
Livestock owned (TLU)	4.216	2.287	0	9.85
Total land owned (Hectare)	1.86	1.315	0	7.2
Off/non-farm income (ETB in 1000)	3.935	5.126	0	16
Extension service (No of service)	7.539	5.711	0	18
Distance to market (Minutes of walk)	66.04	67.19	5	90

Source: Own survey result

With regard to the allocation of land resources the mean area of land allocated for *tef* production by sample households was 1.86 hectares with a standard deviation of 131. The non-farm activities in the study areas include animal cart, daily laborer, remittance, and petty trade. The mean income obtained from off/non-farm income was 3.935 ET Birr with a standard deviation of 5.126 (Table 2). The agricultural extension/ development agents are the main source of information for crop production and marketing for farmers. The mean frequency of extension service provided for sample households was 7.5 days with a standard deviation of 5.7. The distance from home to the nearest market place where farmers get required inputs for production and sale of produce was on average of 66 minutes of walk with standard deviations of 67.19.

3.1.2. Farm Inputs Used in *Tef* Production by Sample Households

The farm inputs used in *tef* production were land, improved seed, labor, oxen, and fertilizers. The production function for this study was estimated using five input variables. The survey result indicates that the average *tef* outputs produced is 1132 kg with a standard deviation of 276.3, which is the dependent variable in the production function. The minimum and maximum land areas allocated for *tef* cultivation by sample households is 0.2 hectare and 2.5 hectares whereas the mean area is 1.16 ha with a standard deviation of 0.58 (Table 3). The mean labors used per hectare was 58.34-man-days with a standard deviation of 32.25; the mean oxen draft power used for ploughing per hectare was 25.02 oxen days with a standard deviation of 14.85; whereas the mean fertilizer used per hectare was 175.03 kg with a standard deviation of 77.81.

Table 3. Descriptive statistics of farm inputs used in *tef* production

Variable	Mean	Std. Dev.	Min	Max
Area of *Tef*	1.16	0.587	0.2	2.5
Tef seed (kg)	21.83	8.34	9	32
Labor (Man days)	58.34	32.25	29.3	120
Oxen ploughing (Oxen days)	25.02	14.85	10.36	49.7
Fertilizers (Kg)	175.03	77.81	81.6	300
Tef produced (Kg)	1132	276.3	848	1800

Source: Survey results

3.1.3. Crop Cultivated by Sample Households in the Study Areas

As revealed from Table 4 below sample households in the study areas allocate their land resources for crop production, grazing for livestock, and eucalyptus tree plantation. Among crops cultivated in the study areas, the majors are *tef*, chickpea, grass pea, and wheat with area coverage of 1.16, 0.378, 0.255, and 0.194 hectares, respectively. In terms production, the major contributors of outputs for farmers in the study areas are *tef*, potato, wheat, and chickpea covering average produce of 1293.7, 819.3, 529.8, and 441.7 kgs, respectively. This is an indicator that farmers in the study areas cultivate by rotation cereals with pulse crops to enhance crop productivity and to maintain soil fertility.

Table 4. Crops area coverage and productions by sampled households

Crop type	Areas cultivated		Quantity produced	
	Mean	Std. Dev.	Mean	Std. Dev.
Tef	1.16	0.58	1293.7	771.7
Chick pea	0.378	0.39	441.7	357.12
Grass pea	0.255	0.34	353.5	353.18
Wheat	0.194	0.33	529.8	442.88
Maize	0.164	0.19	337.5	298.47
Lentil	0.029	0.095	95.2	108.11
Spice	0.023	0.119	345	349.96
Potato	0.022	0.074	819.3	1115.1
Sorghum	0.011	0.056	287.5	112.59
Barley	0.016	0.087	272.2	152.29
Faba bean	0.017	0.084	300	292.26

Source: Own survey result

3.2. Econometric Results

The Maximum Likelihood estimates of the parameters of stochastic frontier production functions and determinants of technical inefficiency are presented in Table 5 and Table 7.

3.2.1. Parameter estimates of the SFP model

The technical efficiency levels of sample households in *tef* production were estimated using the stochastic frontier production function (SFP). The input variables used in the stochastic frontier production model were *tef* seed (kg), labor (man-days), oxen (oxen days), fertilizers (kg), and area under *tef* cultivation (hectare). The coefficients of the input variables were estimated under the full frontier production function (Table 5). From the total of five input variables considered in the production function, three of them (*Tef* seed, labor, and areas under *tef*) had a significant effect in explaining the variation in *tef* output among farmers. The model result shows the increased amount of *tef* seed and labour were found to negatively and significantly affect *tef* production at 5% and 1% significance levels, respectively. This indicated that a unit increase of these variables decreases the level of *tef* output and its real. Areas under *tef* cultivation were found to positive and significant at a 1% significance level, which is important variable in shifting the frontier output to the right. The result indicated that each unit increase in areas of land under *tef* increase the level of *tef* output and this implies that there still exists a potential to increase *tef* output by increasing the areas under *tef*. This result is consistent with Zinabu T. *et al.,* (2021).

Table 5. Maximum Likelihood Estimate of Stochastic Frontier Production

Variables	Coefficient	Std.Err.	z -value
Constant	8.605***	0.766	11.230
lnSeed	-0.183**	0.088	-2.090
LnLabour	-0.227*	0.137	-1.650
LnOxen	0.021	0.067	0.310
LnFertilizer	-0.013	0.103	-0.120
LnArea	0.503***	0.139	3.620
Gamma (γ)	0.712***		
Lambda	0.258***		
Log likelihood	-58.24		

Source: Own computation result

Symbols: ***, ** and * indicates significant at 1%, 5% and 10% levels, respectively.

The return to the scale for *tef* production in the study areas was decreasing returns to scale which is 0.94. This implies increasing all inputs beyond the limit leads to the reduction of the output. This is due to the low technological advancement in agricultural sectors and insufficient dissemination.

3.2.2. Technical efficiency scores of sample households

According to the results in Table 6, the efficiency scores of sample respondents indicate that there were wide ranges of differences in technical efficiency among *tef* producer households in the study area. The efficiency scores indicate that the technical efficiency among the households ranges from 24.2% to 96.7%, with standard deviation of 0.129. The mean technical efficiency of sampled households was 84.3%, which shows that on average *tef* producer households was performing below 15.7% of the maximum potential output and it is possible to raise *tef* output by about 15.7% without using additional inputs and if they use inputs on hand efficiently. This result household specific technical efficiency levels are consistent with the findings of (Kusse H. *et al.,* 2018).

Table 6. Technical efficiency measures

Descriptions	Efficiency scores
Mean	0.843
Std. Dev.	0.129
Min	0.242
Max	0.967
Skewness	-1.899
Kurtosis	7.116

Source: Own computation result

The distribution of the TE scores in Figure 2 showed that the majority of households 96(46.6%) technical efficiency score is greater than 90% and also there were also some sample farmers whose technical efficiency levels were below 50%. The result shows that *tef* producers in this category have a room to enhance their wheat production at least by 50%, on average.

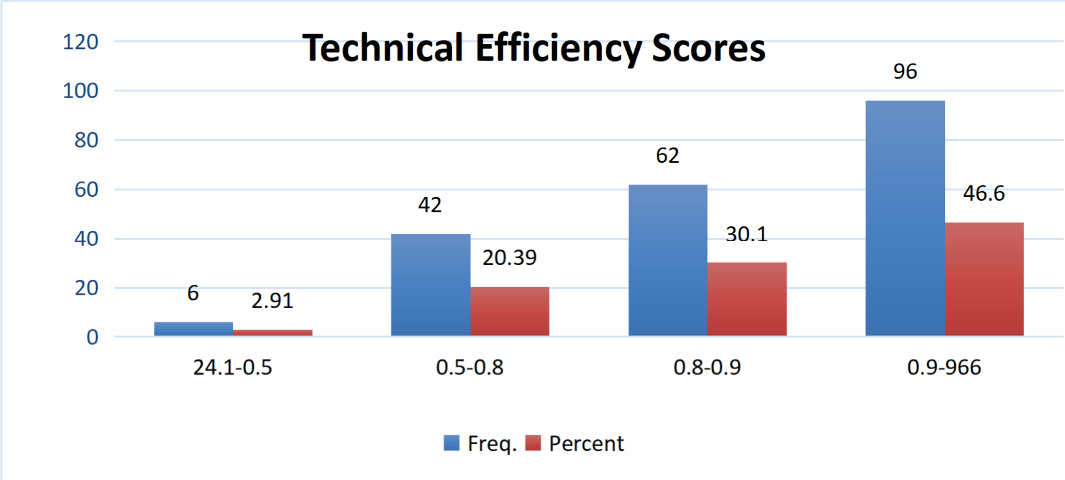

Figure 2. Distribution of *tef* producers' technical efficiency scores

Source: Own computation

The minimum technical efficiency was 24.1% implies that the least performing farmer in the sample was operating 75.9% below the maximum potential output. The maximum TE is 96.6% infers the best performer farmer was only 3.4% below the frontier possibility curve (Figure 2).

3.2.3. 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 variable. Since the dependent variable of the inefficiency function represents the mode of inefficiency, a negative sign on an estimated parameter implies that the associated variable had a positive effect on efficiency. Table 7 presents the determinants of technical inefficiency in *tef* production of sample households.

The results from the stochastic FP model indicated the three variables are significant to affect the technical inefficiency of *tef* producers in Dendi district. The number of livestock owned measured in TLU was statically significant at 10% to affect the technical inefficiency of farmers negatively. This is due to the fact that as the livestock owned increases the farmers' income to purchase important production inputs in cultivating tef and enhance the technical efficiency level (Table 7). The result is supported by the findings of Solomon (2014) who found the effect of livestock ownership on technical inefficiency was found to be negative.

The type of tef seed used by sample households was found to have a significant and negative effect on the technical inefficiency at a 10% significant level. This might be due to the fact that households who use improved *tef* varieties would increase the technical efficiency and better in *tef* production than those households who use local seed. This result is in line with the findings of Asres E., *et al.*, (2014) and Zinabu T. *et al.,* (2021).

Table 7. Stochastic model estimates on different inefficiency of *tef* producers

Variables	Coefficient	Std.Err.	z -value
Constant	-1.215	3.240	-0.370
Education level	0.004	0.140	0.030
Farming experience	-0.020	0.047	-0.430
Livestock owned	-0.323*	0.175	-1.840
Use of improved *tef* seed	-1.272*	0.714	-1.780
Total land owned	0.216	0.277	0.780
Number of plots	-0.221	0.496	-0.450
Access to Credit	-1.133	1.967	-0.580
Off/non-farm income	1.011	1.251	0.810
Distance to market	-1.162**	0.566	-2.050
Extension service	-0.101	0.099	-1.020

Source: Own computation result

Symbols: ** and * indicates significant at 5% and 10% levels, respectively.

Proximity to the district market is found to be significant to influence the technical inefficiency level *tef* producers negatively at a 5% significant level. The result indicates the proximity of *tef* producers provide farmers access to input market and production information and increase the technical efficiency of a farmer (Table 7). The households who have nearest to the district market were more efficient than those households that were far from the market and information.

4. CONCLUSIONS AND RECOMMENDATIONS

Tef is the most important cereal crop contributing 5.5 million tons of output and is cultivated by 6.9 million households in Ethiopia. In the Oromia region, *tef* contributed 2.7 million tons and was cultivated by 2.8 million smallholders whereas in West Shewa *tef* contributed 422,143 tons of production and was cultivated by 368,488 households. The aim of this study was to analyze the level of technical efficiency and identify sources of inefficiency among *tef* cultivating farmers in West Shewa, Ethiopia. The study employed the data obtained from 206 randomly selected households. Both descriptive statistics and econometric models were used. The descriptive statistics were used to analyze household socio-economic characteristics and A Cobb-Douglas stochastic frontier production model with the inefficiency effect was employed simultaneously to analyze the level of technical efficiency and identify the causes of technical efficiency differentials among *tef* producer farmers. The maximum likelihood estimates of the stochastic frontier production model indicated that *tef* output was positively and significantly influenced by areas cultivated, whereas the increased use of seed and labour negatively affected *tef* production.

The mean technical efficiency of sampled households was 84.3%, which shows that on average *tef* producer households had the potential to raise *tef* output by about 15.7% without using additional inputs by employing available inputs efficiently. The return to the scale for *tef* production in the study areas is 0.94 which is decreasing returns to scale and this indicated that to increase *tef* outputs agricultural production technology advancement and disseminations and proportional use of inputs is essential. The estimated results of inefficiency model showed that livestock owned, use of improved seed, and distance to the district market were negatively and significantly affected the technical inefficiency of *tef* producers. The negative coefficient of these parameters to the technical inefficiency indicates that the access and increased use would make *tef* producers productive and technically efficient. Hence, the focus should be given to effective utilization of productive resources and distribution of improved agricultural technologies with improving the existing level of efficiency.

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