Analysis of the Technical, Allocative, and Economic Efficiencies of Tef Producers in Ejersa Lafo District, Central Oromia, Ethiopia

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Abstract
Tef is the most important food and cash crop for more than 70 million people. It is the second-largest crop in terms acreage, but its average productivity is lower compared to other that may arise from different factors. Therefore, this research was intended to assess technical, allocative and economic efficiency of tef producers, and factors affecting technical inefficiency of tef producers using primary data collected from 472 tef producers from Ejersa Lafo district, Oromia, Ethiopia. The result of the stochastic frontier model and Cobb-Douglas production function revealed that the mean technical, allocative, and economic efficiency scores were 80.85%, 88.91% and 71.89% respectively. The result also revealed that all the included production variable; land, labor, fertilizer, chemicals, seed, and size of the plot allotted for tef significantly affected yield per hectare. Moreover, sex, education, experience in tef production, age of the head, distance from farmers' training center and dependence ratio were the variable significantly affected technical inefficiency of teff producers. The conclusion from these results is that there is a room for farmers to reallocate their resources and achieve higher tef yield per hectare by 19.15%, and minimize their cost of tef production per hectare by 28.11%.
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1. BACKGROUND

Tef [*Eragrostis tef* (Zucc.) Trotter] is the most important indigenous cereal crop in Ethiopia, that is the leading crop in terms of acreage being cultivated on more than 3 million hectares, and also the second crop in terms of total production of 57.4 million quintals next to Maize (CSA, 2021). It is the main stapple food crop for more than 70 million people (Cheng et al., 2017; Solomon Chanyalew et al., 2017). Tef is a nutritious crop containing nutrients like carbohydrate, protein, fat, fiber, and minerals (Baye, 2014), and also getting popularity globally being gluten-free and healthy food (Spaenij et al., 2005).

The area under cultivation for tef is expanding over time. But, the productivity of the crop is yet lower compared to other cereals (18.5 quintals/hectare). The productivity potential of the crop at the research field and at the farmers' field also shows wider gap. Different scholars reported different factors that contributing to the low productivity of the crop. Low rate of technology adoption and use of low-yielding local varieties, drought stresses, lodging effects, poor agronomic practices, inefficiency of the farmers, shattering, post-harvest losses were among the factors contributing for low productivity of tef. The existence of such factors significantly affects farmers' efforts to improve production, productivity, income, and food security (Assefa et al., 2015; Tsegay et al., 2015; Negash et al., 2017; Chanyalew et al., 2019).

Enhancing technical efficiency and productivity of smallholder farmers is a key strategy in improving food security and poverty reduction in developing countries as they contribute the lion share in food production. Therefore, this study was intended to assess technical, allocative and economic efficiency of tef farmers in Ejersa Lafo district, central Oromia, Ethiopia.

2. RESEARCH METHODS

2.1. Description of the study area

The study was conducted in Ejersa Lafo district, that is one of the districts in West Shewa zone, Oromia regional state, Ethiopia. The district is located at 70 kilometers to the west of Addis Ababa, and 47 kilometers from Ambo, the capital town of west Shewa zone. The geographical location of the district is in between 9°0'-9°50'N and 38°30'-38°45'E. The area of the district is about 32,365 hectares. Administratively, the district is divided into 17 rural and 3 urban *kebeles*, that are totally 20. Agroecologically, about 74% of the district is classified under highland, and the rest 26% is midland whose altitude is ranging 2000 to 3288 meters. The average temperature of the district is 19.67°C, that ranging from 5.4°C to 26.4°C. The mean annual rainfall of the district also ranges from 750 to 1170mm. The district is mainly characterized by mixed crop and livestock production, and they are major sources of livelihood for the population of the district (Leta and Megersa, 2021; Tolesa et al., 2021).

2.2. Sampling procedure and sample size determination

Ejersa Lafo districts was purposively selected based on its potential of tef production. From the total of 20 *kebeles* in the district, 4 representative kebeles were randomly selected at second stage. Finally, a total of 472 representative sample households from four kebeles were randomly selected using systematic random sampling techniques.

2.3. Data Types and Methods of Collection

Primary and secondary data sources were used. Primary data were collected from 472 sample households using structured and semi-structured questionnaires. Secondary data were collected from different published and unpublished sources like journals articles, reports, books, web sites and records of kebeles and districts.

2.4. Methods of Data Analysis

2.4.1. Descriptive Data Analysis

Under descriptive data analysis, mean, percentage, minimum and maximum were employed to describe and summarize the socio-economic, institutional and demographic factors included in this specific research.

2.4.2. Econometric Data Analysis

Under econometric data analysis section, different methods of efficiency measures like technical efficiency, allocative efficiency and economic efficiency measures were addressed.

2.4.2.1. Technical Efficiency

For this case, technical efficiency was measured using parametric approach, that is the stochastic frontier model. According to the stochastic frontier model, the deviation from the efficient production frontier depends on farm's inefficiency like the factors that can be controlled by the farmer, and the stochastic parameters (the factors that are out of the control of the farmer) (Paul W. Bauer, 1990).

Based on recent literatures, the stochastic frontier model is preferred in measuring the production efficiency compared to other methods like data envelopment analysis for different reasons. For example, data envelopment analysis assumes that all the deviations from the efficient frontier is due to farmer's inefficiency. But, in reality, the variability in agricultural production and productivity may arise from biotic and abiotic factors. Moreover, as it is difficult to get accurate farm records of both input and output from small scale farmers, using data envelopment analysis will become difficult.

In assessing efficiency, the stochastic frontier modelled by different scholars contributed much in measuring the efficiency of agricultural production. In this article, the stochastic frontier model described by Aigner (1977) and Parikh (Parikh and Shah, 1994) was followed. The model follows the stochastic production function of a multiplicative error term that can be expressed as:

$$Y_i = f(X_i, \beta_i)e^{\varepsilon_i} \quad \ldots\ldots 1$$

Where: Y_i = the maximum possible output

X_i = are the vector of inputs (non-stochastic)

β_i = are unknown parameters to be estimated, and

ε_i = is the stochastic disturbance or error term

Taking the natural logarithm of equation 1,

$$\ln Y_i = \beta_0 + \sum_{j=1}^{n} \beta_j \ln X_{ij} + \varepsilon_i \quad \ldots\ldots 2$$

ε_i consists of two independent components u, (the technical inefficiency of the farm) whose value zero for the farm producing on the frontier or negative for the farm producing below the frontier, and v, (the random variability of output as the result of uncontrollable factors). Therefore, equation 2 can be rewritten as:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{n} \beta_j \ln X_{ij} + (v + u) \quad \ldots\ldots 3$$

Stochastic frontier estimation can be performed using singe step and the two-steps estimations. But, the two step estimation has drawbacks and fail to satisfy the assumptions (Kumbhakar and Lovell, 2000). Therefore, for this specific research, the single step estimation of farm inefficiency and factors affecting the farm inefficiency were assessed.

The estimation of the inefficiency score was done using the ratio of the realized output to the stochastic frontier output. Functionally, it can be expressed as:

$$TE_i = \frac{f(X_i, \beta_n)\, e^{V_i - U_i}}{f(X_i, \beta_n)\, e^{V_i}} = e^{-U_i} => e^{f(Z_i, \delta_i) + \omega_i} \quad \ldots\ldots 4$$

Where: u_i = is the inefficiency score for the i^{th} farmer

Z_i = represent the vector of explanatory variables explaining farmers' inefficiency

δi = is the vector of unknown parameters to be estimated, and
ωi = unobservable random variables distributed with 0 mean and unknown variance

Based on equation 4, the technical efficiency score value ranges from zero to one, to mean that the actual production is equal with the frontier production if the value of the score is equal to one, and the farmer is said to be efficient. Following (Battese and Coelli, 1995), the linear functional form of the inefficiency function can be expressed as:

$$u_i = \delta_0 + \sum_{i=1}^{n} \delta_i Z_i + \omega_i \quad \ldots\ldots 5$$

2.4.2.2. Economic Efficiency

Stochastic cost function was used to estimate economic efficiency score. It is the ratio of the efficient cost (minimum cost) to the actual cost. The functional form of the stochastic cost function used for estimating the economic efficiency can be expressed as follows:

$$C_{ij} = f(X_i, Y_i, \beta_i)e^{\omega_i} \quad \ldots\ldots 6$$

Where: C_{ij} = the i[th] farmer's observed cost of tef production
X_i = a vector of inputs used by the i[th] farmer for producing Y_i output of tef
ω_i = the composite error term of μ_i (inefficiency term), and δ_i (the stochastic term), and
β_i = a vector of parameters associated with the production function.

Decomposing the error terms, equation no. 6 can be rewritten by as:

$$C_{ij} = f(X_i, Y_i, \beta_i)e^{(\delta_i+\mu_i)} \quad \ldots\ldots 7$$

So, the economic efficiency, that is the ratio of the observed cost to frontier cost expressed as:

$$EE = \frac{C_i}{C_i^*} \quad \ldots\ldots 8$$

Where: C_i = observed tef production cost for the i[th] farmer, and
C_i^* = the frontier (the efficient cost) of producing tef.

Inserting equations 6 and 7 into 8, the economic efficiency can be expressed as:

$$EE = \frac{f(X_i, Y_i, \beta_i)e^{(\delta_i+\mu_i)}}{f(X_i, Y_i, \beta_i)\, e^{(\delta_i)}} = e^{\mu_i} \quad \ldots\ldots 9$$

Similar to that of technical efficiency, the economic efficiency score also ranges from zero to one, to mean that the score value of one is show that the farmer is cost efficient.

2.4.2.3. Allocative efficiency

Allocative efficiency is the ratio of the economic efficiency to that of technical efficiency. It measures the efficiency of input allocated for producing a specific output, that is tef in this case. Following (Farrell, 1957), the functional form of allocative efficiency is expressed as:

$$AE_i = \frac{EE_i}{TE_i} \quad \ldots\ldots 10$$

Where: AE_i, EE_i and TE_i are allocative, economic and technical efficiency of the i[th] farmer.

Using equations 4, 9 and 10, the allocative efficiency can be rewritten as:

$$AE_i = \frac{e^{\mu_i}}{e^{-\mu_i}} \quad \ldots\ldots 11$$

Where: $e^{\mu i}$ and $e^{-\mu i}$ are economic and technical inefficiency parameters.

3. RESULTS AND DISCUSION

3.1. Descriptive Results

Based on the result in Table 1, the average yield of tef in the study area was about 931.42 kilograms per hectare, with minimum and maximum yields of 250 and 3100 kilograms. Central statistical agency (CSA, 2021) reported that the national and regional average tef production per hectare for Ethiopia and Oromia were 1882 and 1931 kilograms respectively. Based on the above information, the average productivity of tef in the study area was below the national and regional averages.

On average, about 20 man-equivalent labor is required to manage one hectare of tef farm. About, 200 kilograms of fertilizer were used on one hectare of tef production plot, and it was ranged from 50 to 338.55 kilograms. The result also showed that about 25.33 kilograms of seed was used on one hectare of tef production farm, that ranged from 10 to 62.5 kilograms. The average land allocated for tef production was 0.4 hectare, that ranged from 0.08 to 2.13 hectares. Moreover, the average number of tillages for tef was four times, and the mean oxen-day per hectare was 24.18. Finally, households in the study area applies about 1 litter of different chemicals per one hectare of tef production plot (See Table 1).

Table 1. Descriptive results for production variables

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Yield (kg)	472	931.42	408.13	250.0	3100.0
Labor (man)	472	20.432	13.244	7.480	94.350
Fertilizer (kg)	472	199.10	45.041	50.00	338.55
Seed (kg)	472	25.337	10.203	10.00	62.500
Plot size (ha)	472	0.3970	0.3250	0.080	2.1300
Oxen (day)	472	24.187	13.129	8.460	68.770
Chemical (kg)	472	0.9040	0.7160	0.000	6.2500

Source: Computed from own survey

Majority of the sample households, (89.41%) were male headed, while the rest 10.59% were female headed households. The age of the sample households ranged from 20 to 74, with an average of 40.11 years. On average, the household in the study area have an average family member of 5, and an average livestock holding of 7. Moreover, the average educational level of the sample households was 5.4 years of schooling, that ranged from 0 to 15 years. The result also revealed that households in the district have more than 13 years of experiences in tef production (See Table 2).

The mean distance from the main market, farmers' training center (FTC) and tef plot distance from the residence were 4.6, 4.4, and 1.5 kilometers respectively. The result also revealed that only 7.6% of the sample households were credit users. About 33%, 50% and 17% of the sample households have 0, 1 and 2 dependent family members (see Table 2).

Table 2. Descriptive results for demographic, socio-economic and institutional factors

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Sex of the head	472	0.8940	0.3080	0.000	1.0000
Age of the head	472	40.114	11.079	20.00	74.000
Family size	472	4.4810	2.2120	1.000	16.000
Livestock holding	472	7.0640	3.6320	0.000	17.510
Education of the head	472	5.3580	4.1970	0.000	15.000
Experience in potato	472	13.189	8.7930	1.000	47.000
Distance from market	472	4.6030	2.3120	1.000	18.000
Distance from FTC.	472	4.4240	2.1840	0.100	17.000
Access to Credit services	472	0.0760	0.2660	0.000	1.0000
Dependency ratio	472	0.8370	0.6870	0.000	2.0000
Plot distance	472	1.4850	1.4800	0.000	12.000

Source: computed from own survey

3.2. Econometric Results

3.2.1. Estimation of Maximum Likelihood

Stochastic frontier model (SFM) the model used to estimate technical, allocative and economic efficiency of tef producers. Before running the model, variance inflation factor (VIF) test was done, and the mean VIF was 1.19 while the value for all the variables ranged from 1.7 to 1.02.

For its advantage of enabling us conduct estimation of efficiency scores combining both production and inefficiency variables simultaneously in a single step, and also enabling us avoid the bias to be occurred while we are using a two-step estimation, the truncated normal distributional approach is the preferable method. Therefore, stochastic frontier model of the truncated normal distribution was the model used for this specific research, and the model result is presented in Table 3. The result revealed that all the production variables significantly affected tef yield, while only six out of twelve variables (age, sex, education, experience, market distance, and dependence ratio) significantly affected technical inefficiency of tef producers, and the coefficients for each variable were explained as follows:

The result in Table 3 confirms that seed rate used significantly affected tef yield at 1%, and a 1% increase in seed will increase yield by 0.15%. Man-equivalent labor also significantly affected yield at 1%, indicating that increasing labor by 1% will increase the yield by 0.066%. Oxen power used for tillage also significantly affected tef yield at 1%, and from the coefficient, 1% increase in oxen-day will increase yield by 0.107%. Moreover, the amount of fertilizer used per hectare significantly affected tef yield at 1%, and increasing fertilizer by 1% increases tef yield per hectare by 0.58%. The result also revealed that size of the plot allotted for tef production significantly affected the yield at 1%, to mean that increasing land allotted to tef production by 1% is likely to increase the yield per hectare by 0.097%. Finally, application of agrochemicals also significantly affected tef yield at 1%, and increasing chemical application by 1% increase yield by 0.064%. This result is in line with the results reported by other scholars (Mburu et al., 2014; Ahmed et al., 2018; Okello et al., 2019; Wassihun et al, 2019; Andaregie and Astatkie, 2020; Belete, 2020).

Similarly, the result in Table 3 revealed that sex, education and experience in tef production positively and significantly affected tef technical efficiency of tef producers. From the result, male households are more efficient in tef production compared to female headed households. Similarly, more educated household heads were also more efficient in tef production compared to less educated farm households. Moreover, household heads having more experience in tef production were more efficient compared to less experienced farm households. This result is in line with the findings reported by (Wassihun et al, 2019; Andaregie and Astatkie, 2020; Belete, 2020; Khan et al., 2022).

Age of the head, FTC distance and dependence ratio on the other hand negatively and affected technical efficiency of tef producers. Generally seen, aged household heads, households residing away from institutions like farmers' training center and households having more number of dependent family members are are less efficient in tef production (See Table 3).

Table 3. The result of truncated normal distribution of stochastic frontier model

Number of obs. = 301 Waldchi2(6) = 252.35
Log likelihood = -148.2167 Prob > chi2 = 0.0000

Log of yield	Coef.	Std. Err.	z	P>z	[95% Conf. Interval	
Frontier						
Log of seed used	0.155	0.031	5.060	0.000***	0.095	0.215
Log of labor used	0.066	0.024	2.710	0.007***	0.018	0.114
Log of oxen day	0.107	0.023	4.580	0.000***	0.061	0.153
Log of fertilizer	0.583	0.046	12.70	0.000***	0.493	0.673
Log of plot size	0.097	0.018	5.260	0.000***	0.061	0.133
Log of chemical	0.064	0.019	3.300	0.001***	0.026	0.102
_constant	-1.573	0.277	-5.670	0.000***	-2.117	-1.029
Mu						
Sex of the head	-0.067	0.040	-1.660	0.096*	-0.146	0.012
Age of the head	0.008	0.002	5.050	0.000***	0.005	0.011
Family size	0.003	0.006	0.530	0.599	-0.008	0.014
Livestock holding	-0.007	0.004	-1.620	0.105	-0.015	0.001
Education of the head	-0.013	0.003	-3.960	0.000***	-0.019	-0.007
Experience in potato	-0.010	0.002	-5.480	0.000***	-0.014	-0.007
Distance from market	0.005	0.007	0.780	0.434	-0.008	0.019
Distance from FTC	0.012	0.006	1.960	0.050**	0.000	0.024
Access to credit	-0.077	0.048	-1.620	0.106	-0.171	0.016
Extension contacts	-0.024	0.036	-0.650	0.514	-0.095	0.047
Dependency ratio	0.050	0.018	2.870	0.004***	0.016	0.085
Plot size	0.010	0.010	0.980	0.326	-0.010	0.029
_constant	0.091	0.097	0.940	0.348	-0.100	0.282
U-Sigma	-11.306	8.031	-1.410	0.159	-27.048	4.434
V-Sigma	-2.7740	0.066	-42.22	0.000***	-2.903	-2.645
Sigma_u	0.0035	0.0141	0.2500	0.803	0.0000	9.1811
Sigma_v	0.2498	0.0082	30.440	0.000***	0.2343	0.2665
Lambda (λ)	0.0140	0.0164	0.8600	0.392	-0.0181	0.0462

*, ** and *** shows the level of significance at 10%, 5% and 1%

Source: Computed from own survey

3.2.2. Estimation of Efficiency scores

Technical, allocative and economic efficiency scores were estimated and the result was presented in Table 4. From the result, the mean technical, allocative and economic efficiency for the sample households were 80.85, 88.91 and 71.89 percent respectively. This is to mean that households in the district can increase their tef production by 19.15%, and can also reduce their cost of tef production by 28.11%. This result is similar with the findings reported by (Ahmed and Melesse, 2018; Okello et al., 2019; Tesfaw et al., 2021).

Table 4. Technical, allocative and economic efficiency scores

Variable	Obs.	Mean	Std. Dev	Minimum	Maximum
Technical efficiency (TE)	465	0.80858	0.10799	0.53961	0.99991
Allocative efficiency (AE)	465	0.88917	0.05217	0.75275	0.98515
Economic efficiency (EE)	465	0.71896	0.13617	0.40840	0.98436

Source: Computed from own survey data

4. CONCLUSION AND RECOMMENDATIONS

The aim of this research was to assess the technical, allocative and economic efficiency of tef producers in central Oromia, Ethiopia. The mean tef production per hectare was 931 kilograms, that ranged from 250 to 3100 kilograms, and the stochastic frontier model result revealed that the mean technical, allocative and economic efficiency of tef producers were 80.85%, 88.91% and 71.89% respectively. The result also revealed that all the included production variable; land, labor, fertilizer, chemicals, seed, and size of plot allotted for tef positively and significantly affected tef yield per hectare. Moreover, sex, education, experience in tef production, age of the head, FTC distance and dependence ratio were the variable significantly affected technical inefficiency of teff producers. The conclusion from these results is that there is a room in which farmers reallocate their resources and achieve higher yield per hectare by 19.15%, and minimize their cost of tef production per hectare by 28.11%. To improve production efficiency and attain the highest possible yield of tef per hectare that contributing in ensuring food security, improving household income and alleviate poverty, policy interventions improving technical, allocative and economic efficiency like expansion of institutions providing the required technical, financial and material facilities for smallholder farmers is paramount important as it contributes much in improving efficiency and reduce inefficiency.

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