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Analysis of Levels and Determinants of Technical Efficiency of Teff Producing Farmers: The Case of East Gojam Zone, Amhara Region, Ethiopia

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Abstract
This study explores Technical Efficiency level of smallholder teff production and also investigates socioeconomic determinants explaining the variation in Technical Efficiency among smallholder teff farmers using 396 random sample farm households in East Gojam Zone of Amhara regional state, Ethiopia. Cobb-Douglas Stochastic Frontier Model was fitted to estimate farm level technical efficiency and the associated efficiency scores since the function has been one of the most widely used models among the potential algebraic forms of production function in most empirical studies of agricultural production analysis. Both Maximum Likelihood (ML) and quantile regression (QR) techniques were employed to conduct the analysis of technical efficiency determinants. And the study revealed that a one % increase in the input level of plot size, seed, fertilizer, man-days and oxendays respectively produce a return of 0.30, 0.11, 0.02, 0.28 and 0.14% increase in output, keeping all other factors constant. In general, the result had underlined farmer's opportunity to boost their productivity by optimizing the level of the inputs they are using. On this study the mean levels of the actual and potential output during the production year were 14.00 qt/ha and 21.07 qt/ha and, hence, with 7.07Qt/ha yield gap. Therefore, the ratio of the average yield gap to the average actual yield entails the possibility to increase the average plot level output by 50.5% through improving producers TE under the prevailing production input and technology level. The study also identified that farmers with more fertile plots are technically efficient as compared to those who cultivate marginal lands, keeping all other factors constant. Besides, those teff farmers who use compost have lower inefficiency as compared to those farmers who do not utilize compost in the study area. Moreover, education level influenced efficiency of teff farmers positively. Therefore, the study recommends the concerned bodies to give emphasis to promote education, and to have integrated soil fertility management policy targeting soil fertility enhancement to move the marginalized smallholder farmers TE closer to the frontier.
Keywords: Technical efficiency, Stochastic frontier model, Quantile regression, Teff, Amhara, Ethiopia
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1. Background

Ethiopia is one of the least developed countries and found in East Africa. Its macroeconomic outlook has steadily posted robust growth over the past few decades. Nevertheless, the country is predominantly an agrarian society whereby agriculture accounts for 36 percent of the GDP while the service sector has almost equal contribution to the GDP followed by the industrial sector with 23 percent share. Besides, eighty percent of exports comes from agriculture that employs an estimated 75 percent of the country's workforce compared to less than 3% in the food secure developed countries. Moreover, irrigated farmland constitutes only five percent of the land while crop yields from smallholder farmers are below regional averages. In addition, there is weak market linkages, recurrent drought and limited use of improved seeds, fertilizers and pesticides. Although, the sector faces all these challenges, agriculture-led economic growth that Ethiopia follows can bring about a long-lasting solution to Ethiopia's chronic poverty and food insecurity.

Crop production is dominant in Ethiopian agriculture, and the crop production in turn is cereal farming dominated. For instance, cereals production respectively constituted 81.2% and 88.4% of the total grain area and production in 2020/21 main cropping season because they are the principal staple crops. Teff (Eragrostis tef), maize, sorghum and wheat are the principal four crops with a respective share of 22.6%, 19.5%, 12.9% and 14.6% of the total grain cultivated area. In the same production year, maize, teff, wheat and sorghum made up 30.9%, 16.1%, 16.9% and 13.2% of the total grain production, in the same order. In the given production year, teff ranks least in cereal yield with 18.82 Qt/ha while it is the 2nd cereal crop farming enterprise employing about 6.9 million smallholder cereal producers next to maize (CSA 2020/21).

According to the CSA annual agricultural survey report for the period 2011/12 to 2020/21, contribution of teff farming to the national economy had exhibited a steady annual upward growth. During the aforementioned period, the national teff production had increased from 34.98 million quintals in 2011/12 to 55.10 million quintals in 2020/21 growing on the average at 5.4 percent annually. The observed production growth was primarily owing to the effect of growth in teff yield that had grown from 12.81 to 18.82 quintals per hectare with an average annual growth rate of 4.4%. On the other hand, national teff cultivated area and the number of smallholder teff producers had not shown a significant positive change throughout the period unlike other cereal crops like maize perhaps as a result of higher productivity of other attractive cereal crop enterprises (Table 1). The steady growth of teff production showed over the last 10 years coupled with one of the key positions it assumes in the national grain production entails the need to improve its productivity through research.

Table 1. Compiled 10 years Teff production time series data (2011/12-2020/21)

Year	No. of producers (MP)	Area (MH)	Production (M Qt)	Yield(Qt/ha)
2020/21	6.87	2.93	55.10	18.82
2019/20	7.15	3.10	57.36	18.50
2018/19	6.78	3.08	54.03	17.56
2017/18	6.77	3.02	52.83	17.48
2016/17	7.00	3.02	50.20	16.64
2015/16	6.56	2.87	44.71	15.60
2014/15	6.54	3.02	47.51	15.75
2013/14	6.61	3.02	44.19	14.65
2012/13	6.28	2.73	37.65	13.79
2011/12	6.30	2.73	34.98	12.81

Source CSA-AASS report for the production period 2011/12-2020/21

Note: MP-million producers, MH-million hectares, M Qt-million Quintals

The use of improved varieties, mineral fertilizers and improved access to extension services have a significant contribution to Ethiopia's yield improvements which in turn has played a part to the decrease in household poverty (Zeng et al., 2015) and the improvement of food security (Abate et al., 2015). Yet, as Saron and Tilahun (Saron and Tilahun, 2020) explain a significantly higher yield and better quality of crop products are obtained from improved teff variety compared to local varieties. Besides, the average on station yield potential in the country is greater than the farmers' varieties yield bench marks. This suggests the existence of an enormous potential to augment teff yield and enhance food security in the country. Reducing the yield gap demands the identification and explanation of factors that determine TE at farm level.

In general, countless investigations associated with Technical Efficiency of teff production in Ethiopia were carried out. Many of the investigations were district level and could not give a wide-ranging view of smallholders' teff production efficiency at regional or national level. In bridging some of the information gaps associated with Technical Efficiency, this study strived for exploring Technical Efficiency level of smallholder teff production and investigating socioeconomic determinants explaining the variation in Technical Efficiency among smallholder teff farmers in Amhara regional state, Ethiopia, and hence, bring about a paramount contribution to identifying opportunities for possible policy intervention towards improving teff productivity.

2. Theoretical framework

Conditional on the level of inputs and technology used by an individual farm, the ratio of the observed output to the corresponding frontier output is referred to as the technical efficiency of the farm. Therefore, technical efficiency is defined as the amount by which the level of production for the farm is less than the frontier output (Kibaara, 2005). The degree of technical inefficiency indicates an individual farmer's failure to achieve the highest possible output level given the set of inputs and technology used. The production frontier represents the highest possible output, using the available inputs and technology. Technical efficiency describes the difference between potential and observed yield for a given level of technology and inputs. Technical efficiency functions can be categorized into parametric and non-parametric approaches. Data envelopment analysis (DEA) and the free disposal hull (FDH) are the non-parametric approach while the parametric approach is composed of the stochastic frontier approach (SFA), the thick frontier approach (TFA) and the distribution free approach (DFA). These approaches vary mostly in the assumptions made about the functional form, whether random errors have been accounted for, and the probability distribution assumed for the inefficiency. Another important distinction is between deterministic and stochastic frontiers where Deterministic models assume that any deviation from the frontier function is due to inefficiency (Thiam et al., 2001). This approach, ignored factors beyond the control of the farmers, such as weather conditions, which could influence efficiency. The theory and specification of technical efficiency measures are shown in Aigner et al. (1977), and Meeusen and Van den Broeck (1977), who independently proposed and developed models which are thought to correct some limitations in the deterministic frontier approach of estimating efficiency. In the new approach, the error term consists of two components, one being random and the other being a one-sided residual term representing inefficiency. The stochastic production function which incorporates effects of inefficiency and exogenous shocks is given by the following equation.

$$Y_i = f(x;\beta) * \exp(v_i - u_i), where\ v_i >= 0, u_i \leq 0,$$

Where, Y_i- represent output from firm i, $\beta\ is$ vector of model parameters to be estimated, x is vector of inputs used in the production process, $f(x;\beta)$is a true representation of a farm production function, u_i is non negative random variables capturing technical inefficiency assumed to be NIID (0, σ^2_u) and v_i is random variable reflecting effect of statistical noise. The technical efficiency of individual farmers is defined in terms of the ratio of observed output to the corresponding frontiers output, conditional on the level of input used by the farmers. Hence the technical efficiency of the farmer is expressed as follows.

$TE = \frac{Y_i}{Y_I^M} = \frac{f(x;\beta)*\exp(v-u)}{f(x;\beta)\exp(v)} = \exp(-u)$ where 0<= TE <=1, Y is the observed output of farm i and Y_i^M is the frontiers output of farm i.

Estimation of Production Function

The teff production system in the study area was assumed to follow Cobb-Douglas production function. Consequently Cobb-Douglas Stochastic Frontier Model was fitted to estimate farm level technical efficiency and the associated efficiency score. The fitted log transformed Cobb-Douglas Stochastic Frontier model is described as follows.

$$Y_i = \beta_0 + \sum_{j=0}^{n} \beta_i lnX_{ij} + V_i - U_i$$

where ln represents the natural logarithm; n denotes total number of input variable included in CD; j represents inputs used; i represents the ith teff plot in the sample; Y_i represents the actual output of the ith teff plot; X_{ij} denotes jth input variables applied in the ith teff plot; β stands for the vector of unknown parameters to be estimated; The symmetric component (v_i) is assumed to be independently and identically distributed as N (0, σ^2_v). On the other hand, u_i captures the technical inefficiency of the farmer.

Maximum Likelihood estimation technique was used to estimate the model parameters $\beta_i^{'}s$ and the stochastic and the efficiency model variances $(\sigma^2 = \sigma_u^2 + \sigma_v^2)$ and $\gamma = \frac{\sigma_u^2}{\sigma^2}$ respectively. Following the estimation of the variances, producer's technical efficiency was estimated using Jondrow *et al*. (1982) approach given below.

$$E[u|v-u] or\ E[u|v+u]\ or \left(\widehat{E}(u|\varepsilon) = \frac{\sigma\lambda}{1+\sigma^2}\left[\frac{f\left(\frac{\varepsilon\lambda}{\sigma}\right)}{1-\boldsymbol{F}\left(\frac{\varepsilon\lambda}{\sigma}\right)} - \frac{\varepsilon\lambda}{\sigma}\right]\right), \varepsilon = v \pm u$$

Where f and F represent the standard normal density and cumulative distribution functions, respectively, and: $\lambda("signal\ to\ noise = \frac{\sigma_u}{\sigma_v})$. The fact that the estimated λ greater than 1 and significantly different from zero implies the presence of inefficiency effect within the model.

Based on Battese and Corra (1977) the existence of inefficiency was also tested using γ ($\frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$) parameter. It is interpreted as the percentage of the variation in output that is due to technical inefficiency. Likewise, the significance of σ_u^2 was tested to see whether the conventional average production function adequately represent the data or not.

Estimation of Technical Efficiency

The technical efficiency of individual teff plots is defined in terms of the ratio of observed output to the corresponding frontiers output, conditional on the level of input used by the plots. Hence the technical efficiency of the teff plots is expressed as follows.

$$TE_i = \frac{Y_i}{Y_I^M} = \frac{f(x;\beta) * \exp(v-u)}{f(x;\beta)\exp(v)} = \exp(-u)$$

Where 0<= TE_i <=1, Y is the observed output of plot i and Y^M is the frontiers output. The technical inefficiency (Ui) could be estimated by subtracting TE_i from unity.

Determinants of technical efficiency

This study fits ML estimation and QR that relate efficiency scores to selected producers' characters aiming to identify determinants of technical efficiency. ML summarizes the average relationship between the efficiency determinant factors considered and TE level based on the conditional mean function E(y|x). However, only a partial view of the relationship is provided using this technique. The QR shows the relation between TE determinant factors considered and specific percentiles (or quantiles) of the TE. It indicates changes in the quantiles of the response. ML and QR models fitted are shown as follows.

ML estimates were produced following one stage approach, which includes all inefficiency explanatory variables and conventional input variables simultaneously.

$$Ml: --- \ lnY_i = \beta_0 + \sum_{j=0}^{n} \beta_j X_{ij} + \sum_{k=1}^{n} \sum_{\substack{j=1 \\ j\neq k}}^{n} \beta_{kj} X_{ik} X_{ij} + V_i - U_i + \sum_{i=1}^{m} \delta_i Z_{ik}$$

In the above equation, the term $\sum_{i=1}^{m} \delta_i Z_{ik}$ stands for the inefficiency determinants analysis. where, Z stands for k^{th} inefficiency explanatory, δ_i unknown parameters to be estimated.

QR estimates were produced at 25^{th}, 50^{th}, 75^{th} and 95^{th} quantiles which produces four different regression models estimates.

$$QR: ---------TE_{jki} = \delta_0 + \sum_{k=1}^{m} \delta_k Z_{ki} + \varepsilon_{ji}$$

Where, U_i is the technical inefficiency effect for the i^{th} plot, δ_k is the coefficient of explanatory variable k. The Z_k stands for k^{th} inefficiency explanatory variable, j stands for quantiles.

3. Research sites, sampling and data collection

The study was conducted in two districts of the Misrak Gojam zone of Amhara region namely, Enemay and, Shebel Berenta which were selected purposively. Amhara region is the second largest teff producer in the country with a share of about 35 and 37 percent of the crop national acreage and the associated production, respectively. Misrak Gojam zone is the region main teff producer. For instance, in 2020/21 cropping season it was accountable for 22 and 26 percent of the region tef acreage and production. Currently, teff is the major livelihood base for 480,052 households of the zone (CSA, 2020/21). The study use subset of a national level data collected by EIAR in 2015 main cropping season. EIAR used stratified two stage sampling design for the study. The two study districts were the stratums while each teff producing kebeles in the district form the primary sampling unit (PSU's). Teff producers in each kebele constitute the second stage sampling unit (SSUs). The list of teff producing kebeles and households prepared by each district agricultural office was used as primary and secondary stage sampling frame. Using simple random sampling technique, three kebeles per district and 68 producers per sampled kebeles were selected. Totally 396 teff producing households were studied. Summary of descriptive statistics of major variables used in the econometric models is placed in the table underneath.

Table 2. Summary of descriptive statistics of major variables used in the econometric models

Variable	**Variable description**	**Mean (Std.Dev)**
Input and output variables		
YieldPH	Productivity realized (kg/ha)	1400.03(735.86)
Area	Plot size meter square	0.34(0.19)
Frate	Fertilizer amount (DAP + UREA) in kg	254.71(174.43)
Srate	Seed amount used in kg	21.27(15.63)
MdaysPH	Labor used in man days	156.55(79.98)
OxendaysPH	Number of oxen days	15.21(3.21)
Socioeconomic characteristics		
AGE	Age of household head	43.24(10.25)
SEX	Gender of household head (%) (male)	0.98(0.14)
Education	Educational status of the household head (%)	
	Illiterate	0.37 (0.48)
	Religious/grade one	0.26(0.44(
	First cycle	0.24(0.42)
	Second cycle	0.02(0.15)
	above second cycle	0.11(0.31)
Distance	Distance from residence to plot	26.23(25.81)
CulTefftype	Cultivated teff type (%)	
	White Teff |	0.86(0.0.35)
	Red Teff |	0.14 (0.35)
PlotSoilFer	Plot soil fertility status (%)	
	Good	0.46(0.50)
	Medium	0.40(0.49)
	Poor	0.14(0.35)
PlotSlop	Cultivated plot slope (%)	
	slope (flat)	0.46(0.50)
	Medium slope	0.46(0.50)
	Steep slope	0.08(0.27)
SoilType	Cultivated plot soil type (%)	
	Black	0.53(0.50)
	Brown	0.21(0.41)
	Red	0.20(0.20)
	Grey	0.06(0.06)
Compost	Compost application (%)	0.14(0.35)

4. RESULT AND DISCUSSION

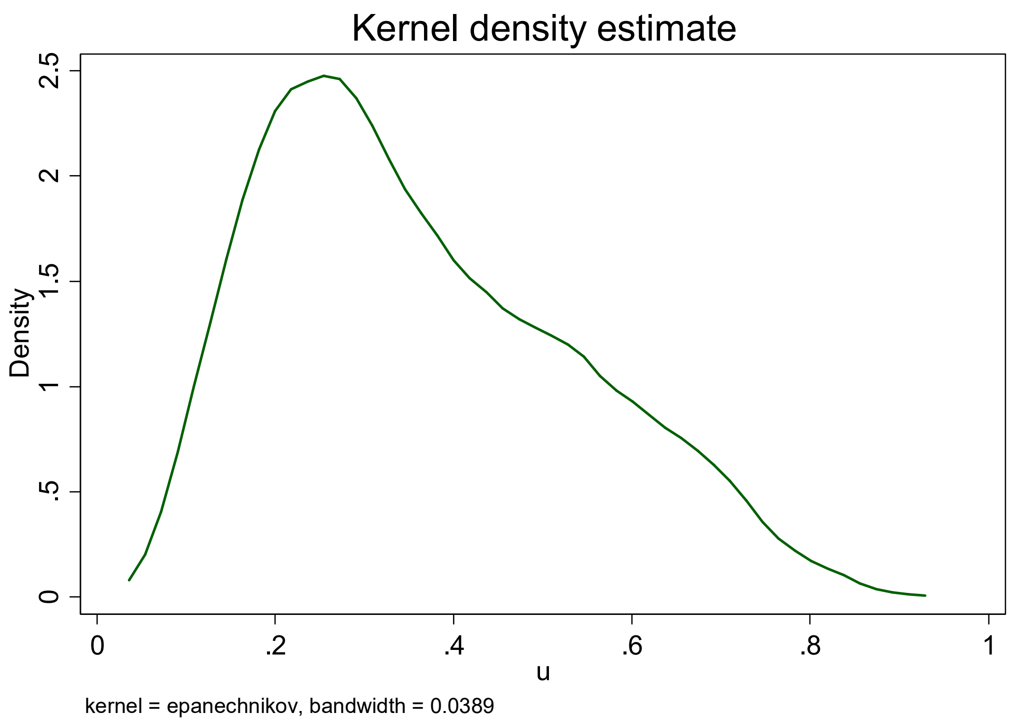
Before fitting the stochastic frontier model the data was checked for possible presence of multicollinearity and heteroscedasticity problem using Breusch-Pagan / Cook-Weisberg and VIF tests respectively. The test result indicates that the data is free from both multicollinearity and heteroscedasticity problems (Table 3 and 4). Before maximum likelihood estimation begins, the skewness of the OLS residuals from the fitted multiple linear regression model was checked in order to decide to use OLS or ML estimation methods. Waldman (1982) has shown that when the OLS residuals have ‘’ negative‟ skewness or similarly when the distribution of inefficiency term (u) is positively skewed the MLE for the frontier model is unique, and no trouble in estimation. For this study OLS residual was negatively skewed while inefficiency term estimated from the half normal stochastic CD production functions showed positive skewedness (Figure 1 and 2). As Waldman, the result obtained infers presence of TE in plot level tef production and appropriateness of stochastic frontier model for TE analysis in the study.

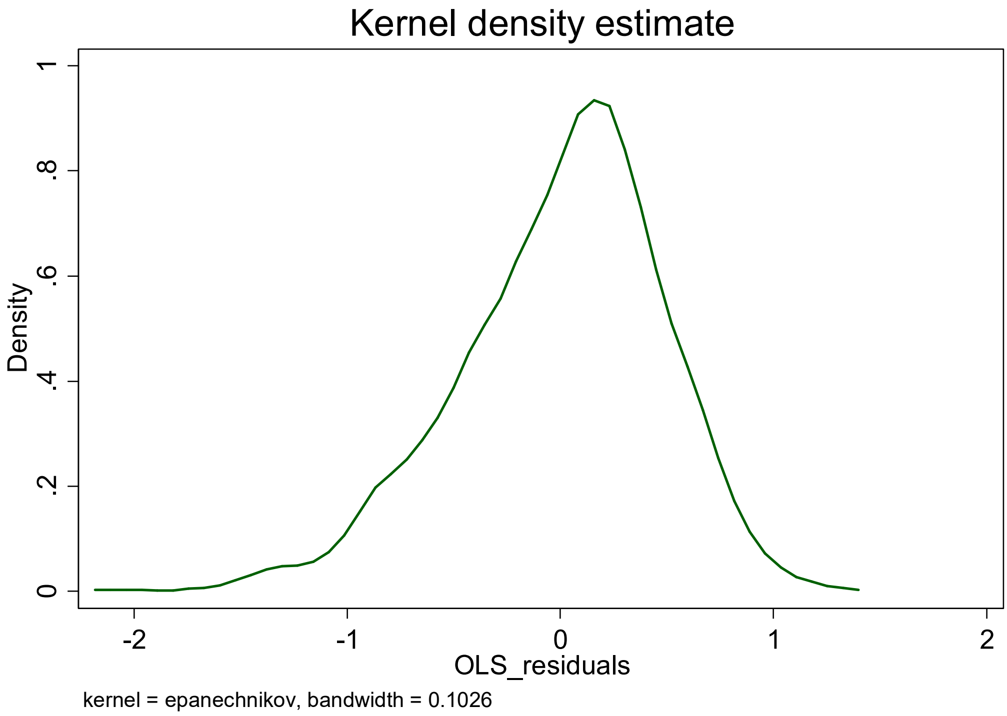
Table 3 test for heteroscedasticity

Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of logproduction
chi2(1) = 2.76
Prob > chi2 = 0.0964

Table 4 Test for multicollinearity

Variable	VIF	1/VIF
logoxendays	8.73	0.11
logplotarea	8.25	0.12
logmandays	2.06	0.49
logseed	1.5	0.67
logfertilizer	1.14	0.88
Mean VIF	4.34	





Aigner, Lovell and Schmidt (1977), likelihood ratio test was employed to validate the hypothesis, H_0:σ^2_u =0 vs H_A: $\sigma^2_u \neq 0$, to see whether the average production function (OLS) best fit the data or not. Ho was rejected at 1% level of significance implying appropriateness of the fitted CD Stochastic Frontier Production Function over the convectional production function which is estimated by OLS. This test result, entails presence of significant TE variation among plots. Also, the estimated lambda (λ) value (2.43) implies that the discrepancy between the observed and the maximum attainable plot levels output is dominated by variability emanating from the TE level the associated teff plots were managed. Over all significance test was employed to see if at least one of the conventional production inputs significantly affect the observed production output at 0.01 level of significance. The test conducted confirmed joint significant effect of the productive factors. Consequently, individual effects of the productive factors on the technical efficiency level was assessed via standard normal distribution test.

All the estimated coefficients in the model for productive factors were positive. All the five inputs considered in the production function had a significant effect in explaining the variation in teff production among plots. The estimated coefficients for land, labour, seed and fertilizer were significant at 1% level of significance while the coefficient of oxendays was significant at 5% level of significance (Table 5). Kaleb et al (2016) got in similar result in study conducted at country, Ethiopia, level. Also, Moges (2016) has found similar result except for significance of seed effect for similar activity conducted in Jamma district, Ethiopia. Solomon (2014) in his effort to establish technical efficiency of major crop production has found land, fertilizer and seed having positive significant effect in enhancing farmer's technical efficiency. The positive coefficient for all parameters indicates that all the inputs have increasing returns to scale effect. The result entails that a one % increase in the input level of plot size, seed, fertilizer, man-days and oxendays respectively produce a return of 0.30, 0.11, 0.02, 0.28 and 0.14% increase in output, keeping all other factors constant. In general, the result had underlined farmer's opportunity to boost their productivity by optimizing the level of the inputs they are using.

Table 5. Maximum likely hood estimates for Cobb-Douglas production function

logproduction	Coef.	Std. Err.	Z
logoxendays	0.14	0.06	2.2**
logplotarea	0.30	0.07	4.4***
logseed	0.11	0.02	4.48***
logfertilizer	0.02	0.01	4.09***
logmandays	0.28	0.03	8.55***
_cons	5.27	0.20	25.88
σ^2_u	0.65	0.03	20.25***
σ^2_v	0.27	0.02	13.89
λ	2.43	0.05	50.85***
ϒ	70.65		
Log likelihood	-651		
N	1002		

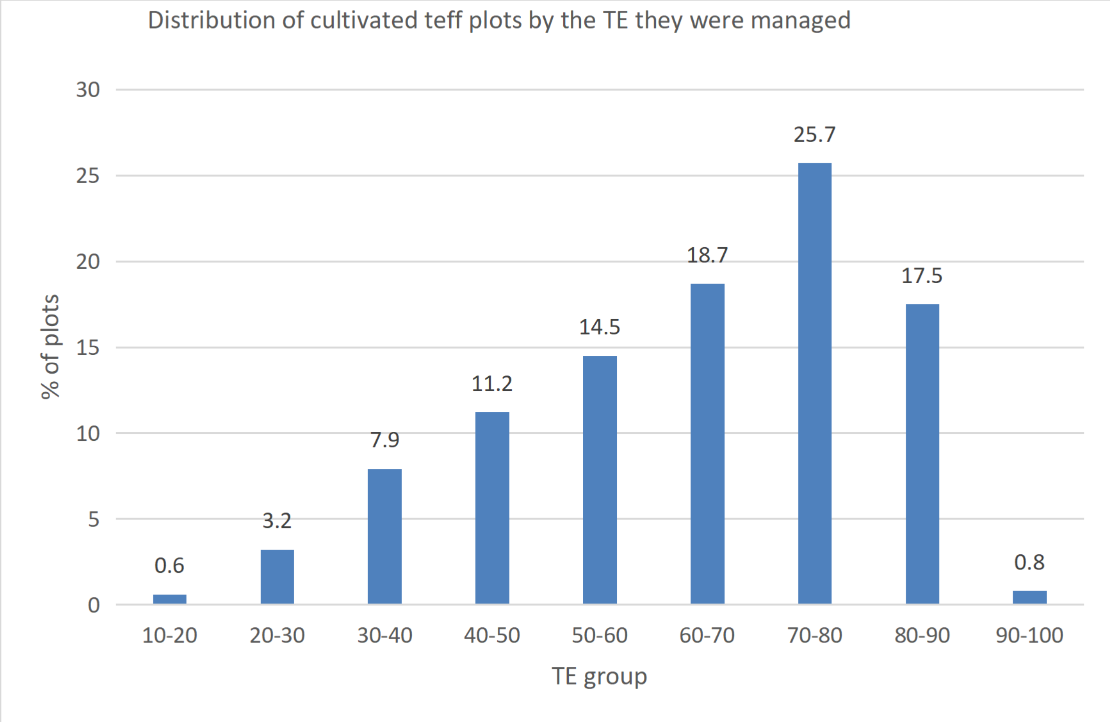
The MLL estimation of the frontier model gave the value for the parameter (γ), which is the ratio of the variance of the inefficiency component to the total error term ($\gamma^2 = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$). The γ value measured the extent of variability between observed and frontier output that is affected by the technical inefficiency. The ML estimated γ value (0.7065) indicates that 70.6% of the variation among smallholder cultivated teff plots was due to technical inefficiency (Table 5). As figure 3 depicts, the distribution of the TE scores is skewed to the lower side. Majority (more than 77.3 %) of the cultivated plots were managed with TE score greater than or equal to 50%. More than 75.5% of sampled plots have a TE score above 80% while only 22.7% of the plots were managed with TE level below 50%.

Table 6 presents summary of the estimated plot level teff production TE scores by district. The TE analysis estimated that average technical efficiency score at which plot level teff production managed to be 64% with a standard error of 0.12. This means, the average output obtained is only 64% of the potential maximum output from a given mix of production inputs. The distribution of the technical efficiency score ranges from 18% to 93% which entails that if the average farmer in the sample was to achieve the technical efficiency level of its most efficient counterpart, it could realize a 25.0% increase in output by improving technical efficiency with existing technology

Teff plots in the two districts considered in the study were managed with mildly different average TE level. For the least operating 25% of the plots the optimum TE level was 53% while for best operating similar proportion of farms the minimum efficiency level was 79%. The middle 50% of the plots were operating with TE level which ranges from 53 to 70%. The minimum TE level (11%) was registered in Shebel-Berenta while the maximum (93%) achieved in Enemay (Table 6).

Table 6 Farm level technical efficiency by district

District	min	max	mean	p25	p50	p75	p95
Enemay	0.16	0.93	0.65	0.53	0.70	0.79	0.88
Shebel Berenta	0.11	0.90	0.62	0.50	0.65	0.76	0.85
Total	0.11	0.93	0.64	0.51	0.67	0.77	0.86



The stochastic production frontier depicts the maximum output which can be produced using a given vector of inputs, i.e. the technically efficient yield. The difference between the technically efficient yield and actual yield is defined as the efficiency yield gap (Silva et al. 2017). The efficiency yield gap shows the extra yield that could be attained using the same level of inputs, when used optimally in production. The efficiency yield gap measures the extent to which farmers could produce more by using the same inputs in the same production condition, but with improved practices regarding the timing, placement and form of the inputs applied. On this study the mean levels of the actual and potential output during the production year were 14.00 qt/ha and 21.07 qt/ha, with the standard error of 7.36 qt/ha and 6.75qt/ha, respectively. Using paired sample t-test, the actual and the potential mean yield were compared and the observed mean deference (7.07Qt/ha) was found significant at 1% level of significance (Table 7). The ratio of the average yield gap to the average actual yield entails the possibility to increase the average plot level output by 50.5% through improving producers TE under the prevailing production input and technology level.

Table 7 Yield Gap analysis output

Variable	Mean	Std. Dev.
Average Fortier productivity (qt/ha)	2107	675
Actual yield obtained (qt/ha)	1400	736
Yield gap	707	304

This study emphasized to provide an empirical evidence on the determinants of productivity variability emanated from TE difference among smallholder teff farmers in the study area. Mere knowledge of technical inefficiency level of farmers might not be useful unless the determinants of the inefficiency are detected. Thus, the study had attempted to detect farm and farmer-specific characteristics that had affected TE after identifying the existence of significant TE deference in teff production. The TE determining analysis takes into account demographic factors, (age, sex and education) and the biophysical and socio economic factors such as soil fertility, distance of farmland from residence, slope of the farmland, use of compost, type of teff and district. The ML and QR methods estimated the parameters of the explanatory variables in the TE model, and the dependent variable of the model was inefficiency. The negative signs implied that an increase in the explanatory variable would decrease the corresponding level of inefficiency, that is, improvement of efficiency, and the positive sign is interpreted inversely. QR analysis was conducted to compare how some percentiles of the TE may be more affected by certain socioeconomic characteristics than other percentiles. Table 9 presents coefficients of TE model estimated by ML and QR (25th, 50th, 75th and 95th quantiles). TE effects of the six factors namely, age, district, distance of farmland from residence, teff type, soil fertility and compost use were significant and in conformity with the prior economic expectation. Those socioeconomic and biophysical factors that show statistically significant effect on smallholder teff producers TE level are elaborated as follows.

Education level is expected to influence TE positively. However, The ML estimated for TE effect of education was insignificant. Nevertheless, the QR estimate for the 25th and 75th quartiles were positive and significant at 10% and 5% level of significance for those teff producers who attended first cycle education while the QR estimate for the 75th quartiles were positive and significant at 10% level of significance for those teff producers who attended above second cycle education. This indicates that education is much more important and has a positive significant effect for those teff poducers who are operating at higher level of efficiency. On the contrary, age has a significant positive effect, at 10% level of significance, on inefficiency in the study area. That is, as age increases, teff producers are becoming less efficient as compared to their younger counterparts in the study area.

Traditional soil fertility regeneration has become less effective since there has been increased pressure on crop lands. Therefore, those farmers that face fewer options would be compelled to cultivate on marginal lands that brings about serious crop failure incidence. Teff farmers in the study area were opted to rate their teff plots fertility status as good, medium and low and only 46% percent of the cultivated plots were rated as good. The ML and QR estimates for output effect of teff plots soil fertility status was found significant at 1% level of significance. The result infered that there was direct relationship between teff producers TE level and their teff plots soil fertility status. This means, farmers with more fertile plots were technically efficient as compared to those who cultivate marginal lands, keeping all other factors constant. Moreover, the QR estimates for output effect of the slope of teff plots was found negative and significant at 5% level of significance for highly performing teff producers.

In addition, the ML estimates for effect of use of compost on inefficiency was found negative and significant at 1% level of significance. This means, those teff farmers who use compost had lower inefficiency as compared to those farmers who do not utilize compost in the study area. This indicates that compost utilization improves the efficiency of smallholder teff farmers, and, hence, their productivity and production.

It was hypothesized that a smallholder farmer that travelled longer distance to the farmland from residence is inefficient than those who are nearer to their farmland since they waste their precious time on travelling that could have otherwise been used in more return generating activities. The ML result for effect of distance of plots on inefficiency was positive and statistically significant at 5%. That is, the longer the distance covered, the higher inefficiency faced by the teff farmer in the study area. To make matters worse, it is more exaggerated in the QR result obtained for the 25th quantiles that is significant at 1%.

The ML result for effect of district on inefficiency was positive and significant at 1%. That is, smallholder farmers in Enemay district were much more efficient than those farmers found in Shebel Berenta district. In addition, White teff producing farmers were more efficient than those farmers that produce Red teff perhaps since they enjoy higher market price or other technical issues that need further investigation.

Table 8 ML and QR estimates compared

Variables	ML Estimates		QR Estimates							
			25th		50th		75th		95th	
	Coef.	T	Coef.	T	Coef.	T	Coef.	t	Coef.	T
District										
Shebel Berenta	0.35	2.86***	-0.07	-3.78***	-0.04	-2.46**	-0.04	-4.03***	-0.04	-3.86***
Sex										
Male	-0.37	-1.01	0.09	1.39	0.00	-0.01	0.02	0.47	0.00	-0.07
Age	0.01	1.65*	-0.00	-2.08**	0.00	-1.19	0.00	0.15	0.00	0.10
Edugroup										
Religious/grade one	-0.12	-0.84	0.02	0.85	0.00	-0.14	0.00	0.33	0.01	0.43
First cycle	-0.24	-1.56	0.04	1.78*	0.03	1.50	0.03	2.21**	0.01	1.10
Second cycle	-0.20	-0.51	-0.01	-0.11	-0.04	-0.83	-0.01	-0.44	0.02	0.75
above second cycle	-0.17	-0.92	0.02	0.57	0.02	0.60	0.03	1.86*	0.02	1.29
Distance	0.00	2.05**	0.00	-2.79***	0.00	-1.90*	0.00	-0.10	0.00	-0.22
Teftype										
Red Teff	0.34	2.16**	-0.07	-2.49**	-0.07	-3.33***	-0.05	-3.51***	-0.03	-2.33**
Soilfertility	0.00	0.00								
Medium	0.43	3.43***	-0.06	-2.70***	-0.02	-1.12	-0.04	-3.43***	-0.02	-2.11**
Poor	0.92	5.27***	-0.14	-4.64***	-0.08	-3.62***	-0.06	-4.09***	-0.02	-1.24
Plotslop										
Medium slope	0.10	0.85	0.00	-0.25	-0.02	-1.35	-0.02	-2.32**	0.00	0.08
Steep slope	-0.12	-0.55	0.01	0.35	0.00	-0.15	-0.02	-0.90	-0.01	-0.43
Compst										
Yes	-0.49	-2.60***	0.04	1.42	0.03	1.56	0.02	1.04	-0.01	-0.43
Const	-1.62	-3.46	0.61	8.02	0.77	0.06	0.81	20.30	0.89	22.58

***, **, * indicate significance at 1 percent, 5 percent and 10 percent level respectively.

5. CONCLUSION AND RECOMMENDATION

This study is undertaken to explore Technical Efficiency level of smallholder teff production and investigate socioeconomic determinants explaining the variation in Technical Efficiency among smallholder teff farmers in

East Gojam Zone of Amhara regional state, Ethiopia. It specified Cobb-Duglas production function that has been one of the most widely used model among the potential algebraic forms of production function in most empirical studies of agricultural production analysis. The analysis of technical efficiency determinants was conducted employing both Maximum Likelihood and quantile regression techniques. It is found that all the five inputs considered in the production function had a significant positive effect in explaining the variation in teff production among plots. The positive coefficient for all parameters indicates that all the inputs have increasing returns to scale effect. The result entails that a one % increase in the input level of plot size, seed, fertilizer, man-days and oxendays respectively produce a return of 0.30, 0.11, 0.02, 0.28 and 0.14% increase in output, keeping all other factors constant. In general, the result had underlined farmer's opportunity to boost their productivity by optimizing the level of the inputs they are using. On this study the mean levels of the actual and potential output during the production year were 14.00 qt/ha and 21.07 qt/ha and, hence, with 7.07Qt/ha yield gap. Therefore, the ratio of the average yield gap to the average actual yield entails the possibility to increase the average plot level output by 50.5% through improving producers TE under the prevailing production input and technology level.

Moreover, this study emphasized to provide an empirical evidence on the determinants of productivity variability emanated from TE difference among smallholder teff farmers in the study area. Mere knowledge of technical inefficiency level of farmers might not be useful unless the determinants of the inefficiency are detected. Thus, the study identified that there is direct relationship between teff producers TE level and their teff plots soil fertility status. This means, farmers with more fertile plots are technically efficient as compared to those who cultivate marginal lands, keeping all other factors constant. Besides, those teff farmers who use compost have lower inefficiency as compared to those farmers who do not utilize compost in the study area. This indicates that compost utilization improves the efficiency of smallholder teff farmers, and, hence, their productivity and production. To make matters worse, the longer the distance travelled from home to farm plot, the higher inefficiency faced by the teff farmer in the study area. However, it is found that Education level influenced efficiency of teff farmers positively while as age increases, teff producers are becoming less efficient as compared to their younger counterparts in the study area. Therefore, the study recommends the concerned bodies to give emphasis to promote education, and to have integrated soil fertility management policy targeting soil fertility enhancement to move the marginalized smallholder farmers TE closer to the frontier.

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