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Analysis of Technical Efficiency of Smallholder Maize Production Using Stochastic Frontier Approach: The Case of Amhara Region, Ethiopia

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Abstract: Maize is one of the most important cereal crops in Ethiopia, ranking first in total cereals production (30%). The crop is mainly produced by smallholder farmers. The crop current national yield (4.01t/ha) is far below the world average. Producers' Technical Efficiency (TE) is one of the major factors for its low level of yield. The study sought to examine TE level of smallholder maize production and to explore socioeconomic factors explaining the variation in TE among smallholder maize producers in Amhara regional state, Ethiopia. A Translog stochastic production function model was used to analyze TE while Maximum Likelihood (ML) and Quintile Regression (QR) estimation techniques were employed to identify TE determinant factors. The study used a data collected from 239 maize producing households' selected randomly from seven major maize growing districts of the study region. The study results showed presence of maize production inefficiency, which was accountable for 66.5% of variability between observed and frontier output. The estimated TE of smallholder maize producers in the study area ranges from 20% to 94% with a mean TE of 83%. The study also indicated that number of cultivated maize plots, total cultivated land size, improved variety adoption, contact with extension agents and cultivated plot's soil fertility status as factors which have positive and significant TE effect. It has also identified household size, involvement in formal education and age of household head as factors having significant negative TE effect. The study underlines the possibility to improve the average TE of smallholder maize production in the study area by 17% (4.8qt/ha increase in productivity) through better use of the available resources, given the current state of technology.

Keywords: Technical Efficiency, Yield Gap, Stochastic Frontier Model, Translog Production Function, Quantile Regression, Smallholder Farmers

1. Background

The central role of agricultural productivity in the economic and social agenda of developing countries was reinforced by the Malabo Declaration [17]. This deceleration puts agricultural productivity growth as the main objective of Africa to achieve agriculture-led growth and fulfil its targets on food and nutrition security. In the declaration, it is stated that in order to end hunger in Africa by 2025, at least doubling of agricultural productivity is needed from current levels. The sought productivity enhancement could be achieved either through improvement in production technology or by improving the efficiency of producers under the existing technology [4]. With the obvious capital constraint developing countries face, it may not be possible to adopt improved production technologies to enhance productivity. This leaves working to improve technical efficiency as best feasible option on hand. TE refers to the achievement of maximum potential output from given amounts of factor inputs and technology taking into account physical production relationship [7].

In line with Malabo declaration, the second Ethiopia five-year growth and transformation plan [8], started in 2014/15, targets to increase the average overall smallholder farmers crop productivity from 15.9 to 23.4 tons/ha and specifically grain yield from 2.1 to 3.1 tons/ha. The envisaged marked shift in crop productivity is to be pursued through raising the productivity level of the majority of farmers to the productivity level attained by model farmers and in turn raising the productivity level of model farmers to the level attained by domestic agricultural research centers. Such type of initiatives, strongly benefits from efficiency studies which provide information on the level to which smallholder farms were using the existing technologies efficiently; the potential for raising output with the existing technology; and the possibility to raise productivity by improving both efficiency and technology adoption. Having the stated fact, this study is mainly concerned about improving productivity through enhancing technical efficiency.

Ethiopian agriculture is crop dominated. The crop agriculture in turn is cereal farming dominated. For instance, in 2018/19 main cropping season, cereal production was accountable for 81.4% and 87.5% of the total grain area and production, respectively. Four crops namely, teff, wheat, maize and sorghum accounted for 87% and 89% of the total cereals cultivated area and production in the order of mention. In the same production year, 30%, 17%, 23% and 18% of cereal cultivated area and 19%, 17%, 34% and 18% of the associated production was accounted by the four crops mentioned, respectively. In the given production year, maize tops cereal yield with 4t/ha which was above the national average cereal and grain yield by 1.3 and 1.6 t/ha, respectively. Also, in this production year maize was the top crop farming enterprise employing 65% and 61% of smallholder cereal and grain producers [5].

As the CSA annual agricultural survey report for the period 2009/10 to 2018/19, contribution of maize farming to the national economy had shown a steady annual upward growth. During this period, the national maize production had increased from 4.99 to 9.49 million tons growing at an average annual rate of 8.59%. The observed production growth was partly the cumulative effect of growth in cultivated area, number of producers and yield. In this period, maize cultivated area has increased from 1.77 to 2.37 million hectares of land with an average annual growth rate of 3.07% and the number of smallholder maize producers had grown from 7.15 to 9.86 million. Also, in this period maize yield had grown from 2.20 to 4.01 tons per hectare with an average annual growth rate of 7.04% (Table 1). The steady growth maize production showed over the last 10 years coupled with the key position it assumes in the national grain production entails the need to improve its productivity through research.

Ethiopia's yield improvements have been attributed to the use of modern maize varieties, mineral fertilizers and improved access to extension services. This improvement has contributed to decrease household poverty [19] and improve food security [1]. Yet, the actual maize yield is still far behind on-farm and on-station trial yields [12]. This implies the existence of a huge potential to increase maize yield and improve food security in the country. Narrowing the yield gap requires the identification and explanation of factors that determine TE at farm level. For instance, reviewed studies [9, 14, 18], shows presence of 34%, 27% and 37.7% inefficiency in maize production, respectively.

Table 1. *Compiled 10 years maize production time series data (2009/10-2018/19).*

Year	No. of producers (MP[1])	Area (MH[2])	Production (MT[3])	Yield (t/ha)
2018/19	9.86	2.37	9.49	4.01
2017/18	10.57	2.13	8.40	3.94
2016/17	-	2.14	7.85	3.67
2015/16	9.55	2.11	7.15	3.39
2014/15	8.69	2.11	7.23	3.43
2013/14	8.81	1.99	6.49	3.25
2012/13	9.29	2.01	6.16	3.06
2011/12	-	2.05	6.07	2.95
2010/11	7.96	1.96	4.99	2.54
2009/10	7.15	1.77	3.90	2.20

Source CSA-AASS report for the production period 2009/10-2018/19
Note: MP-million producers, MH-million hectares, MT-million tons.

In general, a number of studies related to TE of maize production in Ethiopia were conducted. Most of these studies were district level and were not able to give a comprehensive view of smallholders' maize production efficiency at state or national level. In bridging some of the information gaps related to TE, the study sought to examine TE level of smallholder maize production and to explore socioeconomic factors explaining the variation in TE among smallholder maize producers in Amhara regional state, Ethiopia. This has a paramount contribution to gain deep insight to understand challenges and constraints in maize production by indicating avenues for possible policy intervention towards improving maize productivity.

2. Conceptual Framework

TE in crop production can be defined as a farmer's ability to maximize outputs given a set of inputs and technology. The degree of technical inefficiency reflects an individual farmer's failure to attain the highest possible output level given the set of inputs and technology used. The highest possible output, using the available inputs and technology, is represented by the production frontier. In general, TE explains the difference between potential and observed yield for a given level of technology and inputs. To this effect, the study utilizes stochastic frontier approach (SFA) developed [2]. The SFA which incorporates effects of inefficiency and exogenous shocks is given by the following equation.

$$Y_i = f(x;\beta) * \exp(v_i - u_i), v_i >= 0, u_i \leq 0 \quad (1)$$

Where, Y_i represents output from firm i, β *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

1 MP-million producers
2 MH-million hectares
3 MT-million tons

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.

$$TE_i = \frac{Y_i}{Y_I^M} = \frac{f(x;\beta)*\exp(v-u)}{f(x;\beta)\exp(v)} = \exp(-u) \quad (2)$$

Where, 0<= TE_i<=1, Y_i is the observed output of farm i and Y_i^M is farm frontiers output.

3. Research Methodology and Area

Efficiency Estimation: In this study, Cobb-Duglas (CD) and Translog (TL) production function were specified and the appropriate one was selected based on log-likelihood ratio tests [6]. The form of log transformed CD and TL production function fitted for this study were defined as follows.

CD based SFM: $lnY_i = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + V_i - U_i$ (3)

TL based SFM:

$$\ln Y_i = \beta + \sum_{j=1}^{n} \beta_j X_{ij} + \sum_{k=1}^{n} \sum_{j=1}^{n} \beta_{jk} X_{ik} X_{ij} + V_i + U_j \quad (4)$$

Where ln denotes the natural logarithm; n represent total number of input variable included in CD or TL production function; j represents inputs used; i represents the i[th] maize plot in the sample; Y_i represents the actual output of the i[th] maize plot; X_{ij} denotes j[th] input variables applied in the i[th] maize 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 and the distributional assumption of the technical inefficiency term, u_i, was identified using the likelihood ratio test.

ML 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 [10] which is given below.

$$E[u|v-u] or\ E[u|v+u]\ or\ \left(\hat{E}(u|\varepsilon] = \frac{\sigma\lambda}{1+\sigma^2}\left[\frac{f\left(\frac{\varepsilon\lambda}{\sigma}\right)}{1-F\left(\frac{\varepsilon\lambda}{\sigma}\right)} - \frac{\varepsilon\lambda}{\sigma}\right]\right), \varepsilon = v \pm u \quad (5)$$

Where, f and F represent the standard normal density and cumulative distribution functions respectively. $\lambda("signal\ to\ noise = \frac{\sigma_u}{\sigma_v})$. 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 [3] 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.

Determinants of TE: In this study ML estimation and QR that relate efficiency scores to selected producers' characters were fitted aiming to identify determinates of technical efficiency. ML summarize the average relationship between the efficiency determinate factors considered and TE level based on the conditional mean function E(y|x). This provides only a partial view of the relationship. The QR show the relation between TE determinant factors considered and specific quantiles of the TE. ML and QR models fitted are presented as follows.

ML estimates were produced following one stage approach, which includes all inefficiency explanatory variables and conventional input variables simultaneously (equation (6)).

$$\ln Y_i = \beta + \sum_{j=1}^{n} \beta_j X_{ij} + \sum_{k=1}^{n} \sum_{j=1}^{n} \beta_{jk} X_{ik} X_{ij} + V_i + U_j + \sum_{i=1}^{m} \delta_i Z_{ik} \quad (6)$$

In equation (8), 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 e estimated.

QR estimates were produced at 25[th], 50[th], 75 [th] and 99 [th] quantiles which produces four different regression models estimates (equation (7)).

QR: ---------$TE_{jki} = \delta_0 + \sum_{k=1}^{m} \delta_k Z_{ki} + \varepsilon_{ji}$ (7)

Where, $TE_{i\ is}$ the technical efficiency effect for the i[th] plot, δ_k is the coefficient of explanatory variable k. The Z_k stands for k[th] efficiency explanatory variable, j stands for quantiles.

Yield Gap Analysis: 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 [15]. 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 production practices. Using the values of the actual output obtained and the predicted technical efficiency scores, the potential output and the yield gap were estimated respectively as follows.

$$Y_i^* = {}^{Y_i}/_{TE_i} \quad (8)$$

$$Y_{gapi} = Y_i^* - Y_i \quad (9)$$

Study area, sample size and sampling methodology: The study examines the TE of maize production in Amhara regional state, Ethiopia. Amhara regional state is second, next to Oromia, major maize producer at national level. For instance, in 2018/19 it was accountable for 30% of the producers, 23.6% of the area and 24.1% of national production. The study used a data collected by Ethiopian Institute of Agricultural Research (EIAR) in 2015. EIAR employed multistage stage sampling technique to collect 239 sample households from the study area. The data on most of the study variables was collected by interviewing the sample respondents. Only plot area and associated yield were objectively measured by the enumerator who administrated the data collection. List of variables considered in the study is presented in the table underneath.

Table 2. *List of variables to considered in production functions and determinants of TE analysis.*

Variable	Description	Expected sign
Output		
Yield	Yield obtained in kilogram	
Production inputs		
Plot size	Plot area in hectare	+
Seed	Amount of seed used in kilogram	+
Fertilizer (UREA+DAP)	Amount of chemical fertilizer used in kilogram	+
Oxen days	Number of days oxen plough used	+
Labour	Man, days used	+
Efficiency determinants		
Sex	Sex of household head (Male, Female	+
Age	Household head age in completed years	+
Education	Participation in formal education (yes, no)-	+
Household size	Number of household members	+/-
Extension	Having extension advice about maize production (yes, no)	+
Number of maize plots	Total number of plots (maize) the household cultivated in the given year	-
Variety use	Improved variety adoption (improved, Local)-	+
Soil fertility	Good, Medium, Low	-
Off farm income	Participation in income generating off farm activities (yes, no)	+/-
Total cultivated land size	Total land size the household cultivated in hectare	+/-

4. Result and Discussion

Model Adequacy: First CD and TL production functions were fitted using Stata version 14 command *sfcross* assuming half normal distribution for the model inefficiency term, U_i. Using loglikelihood ratio test the two fitted models were compared to select the one which best represent plot level maize production function in study area and TL function was selected. A second hypothesis test was conducted to see if the estimated SFM parameters γ and σ_u^2 obtained using the selected TL production function were different from zero. Which entails that significant proportion of the variability in the plot level maize output is attributed to technical inefficiency in production. This hypothesis was rejected as the calculated LR (7.38) was greater than the tabulated χ^2 (2.7) at 1% level of significance. As this result shows, the technical efficiency level at which the cultivated plots were managed was significantly different from plot to plot. After learning presence of significant variability in the TE level at which different maize plots were managed, SFM including a set of candidate TE determinant factors was fitted. The joint possible TE effect of the candidate TE determinant factors was tested (H_0: $\alpha_1 = - - - = \alpha_{13} = 0$) using log likelihood ratio test. Consequently, the null hypothesis which denies the possible TE effect of all candidate regressors was rejected at 1% level of significance (Table 3).

Table 3. *Hypothesis test results.*

Null hypothesis	D.F	Calculated χ^2 (LR)	tabulated (χ^2)	Decision
Which production function, CD or TL, better describe plot level maize production in the study area				
1.H_0: $\beta_7 = \beta_8 - - - = \beta_{21} = 0$	15	63.81	30.58	Reject H_0
Testing presence of maize production technical inefficiency				
2. H_0: No inefficiency ($\boldsymbol{\gamma} = \sigma_u^2 = 0$)	1	7.38	3.84	Reject H_0
Do at least one of the efficiency determinant factors considered in the analysis significantly affect the observed TE level				
3. H_0: $\alpha_1 = - - - = \alpha_{15} = 0$	11	50.43	24.56	Reject H_0

Source: Own computation (2020).

Estimation of production function: Five production inputs (plot area, fertilizer, seed, labour and oxen-days) and their two-way interaction were used in the estimation of the selected TL production functions. Table 4 presents ML estimates of the TL production functions.

Land is a basic input in farming, its relation to output is positive. The MLE coefficient for plot area under maize production had the expected positive signs with an elasticity of 0.530 and was statistically insignificant. This means, in the study area an increase in maize plot size would not be accompanied by significant marginal change in output holding all other inputs constant. But, as the estimated significant and positive coefficient for the interaction effect of plot area with fertilizer entails a unit increase in both inputs will increase maize output by 0.027%. Also, plot area and oxendays have significant but negative output effect. On the contrary to this finding, similar studies had shown statistically significant output effect of plot size [9, 16, 11].

Increasing the quality of seeds can increase the yield potential of the crop by significant folds and thus, is one of the most economical and efficient inputs to agricultural development. The ML estimate (1.004) for its main output effect was significant at 5% level of significance and consistent with its prior expected output effect. This result infers the possibility to increase output by 1.004% as seed increase by 1% holding the other inputs constant. The ML estimated coefficient for seed square was negative and statistically significant at 10% level of significance. This means, positive output effect to be obtained through increasing seed rate will not go long. The study finding was in conformity with the findings of other similar studies [11, 9, 16]. But, one reviewed study had got insignificant result for output effect of seed use [18].

Low fertilizers use is one of the reasons for low agricultural productivity in developing countries in general. In this study increase in use of fertilizer up to the optimum level is expected to affect plot level maize yield positively. The ML estimated coefficient (0.19) for the main output effect of fertilizer was positive and statistically significant at 1% level of significance. The result entails that 1% increase from the current level of fertilizer utilization will be accompanied by 0.19% increase in output ceteris paribus. The ML estimated coefficient for output effect of the fertilizesquare was positive and statistically significant at 1% level of significance which ensures that positive and significant output effect of increasing fertilizer use will continue for long. The study finding was in conformity with findings of other similar studies [11, 9, 16, 18].

In this study labor included family, exchange, and hired labors used in production processes. Accordingly, positive relationship between labour use and plot level maize output was expected. Its ML estimated production elasticity was positive which conform the prior expectation though it was insignificant. This means that the labour use under the current inputs use pattern practiced in the study area is already in excess. The estimated output effect of labour interaction with the remaining four conventional production inputs (plot area, fertilizer, oxendays and seed) was insignificant. Similar studies have estimated significant but negative output effect for labour [11, 9]. On the contrary, other reviewed studies had estimated significant and positive output effect for labour [16, 18].

Livestock draft power used for different farming activities for maize production was measured in oxen days. Hence, oxen power was measured using the total amount of oxen days allocated for different activities of maize production in 2015/16 production season. Consequently, positive relationship between total number of oxen days used (up to the optimum level the cultivate plot demand) and plot level maize output obtained is expected. ML estimated production elasticity of oxendays (-1.211) was significant and negative on the contrary to the prior economic expectation. This result was supported by the findings of other similar studies [9, 18].

Table 4. *Maximum likelihood estimates for TL production function.*

Logproduction	Coef.	Std. Err.	Z
Logplotarea	0.530	0.733	0.72
Logseed	1.004	0.439	2.29**
Logfertilizer	0.190	0.043	4.45***
logTmandays	0.476	0.506	0.94
Logoxendays	-1.211	0.347	-3.49***
logplotarea#logplotarea	0.076	0.109	0.7
logseed#logseed	-0.103	0.057	-1.82*
logfertilizer#logfertilizer	0.011	0.002	4.76***
logTmandays#logTmandays	0.019	0.058	0.32
logoxendays#logoxendays	0.049	0.033	1.47
logplotarea#logseed	0.151	0.122	1.24
logplotarea#logfertilizer	0.027	0.010	2.79***
logplotarea#logTmandays	0.058	0.119	0.49
logplotarea#logoxendays	-0.347	0.104	-3.33***
logseed#logfertilizer	-0.018	0.007	-2.8
logseed#logTmandays	-0.172	0.087	-1.96*
logseed#logoxendays	0.315	0.089	3.54**88
logfertilizer#logTmandays	-0.007	0.008	-0.82
logfertilizer#logoxendays	-0.002	0.009	-0.23
logTmandays#logoxendays	-0.010	0.063	-0.15
_cons	5.251	1.400	3.75***
sigma_u	0.468	0.065	7.15***
sigma_v	0.333	0.031	10.81***
Lambda	1.407	0.092	15.27***
Gamma	0.665		

***, **, * indicate significance at 1%, 5%and 10% levels, respectively.

Technical efficiency estimation: The ML 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 (0.665) indicates that 66.5% of the variation among smallholder cultivated maze plots was due to technical inefficiency (Table 4).

As shown in Figure 1, the distribution of the estimated TE scores is skewed to the right. Majority (more than 97%) of the sample plots have TE score greater than or equal to 50%. More than 83.43% of sampled plots have a TE score above 80% while nearly 3% of the plots were managed with TE level below 50%.

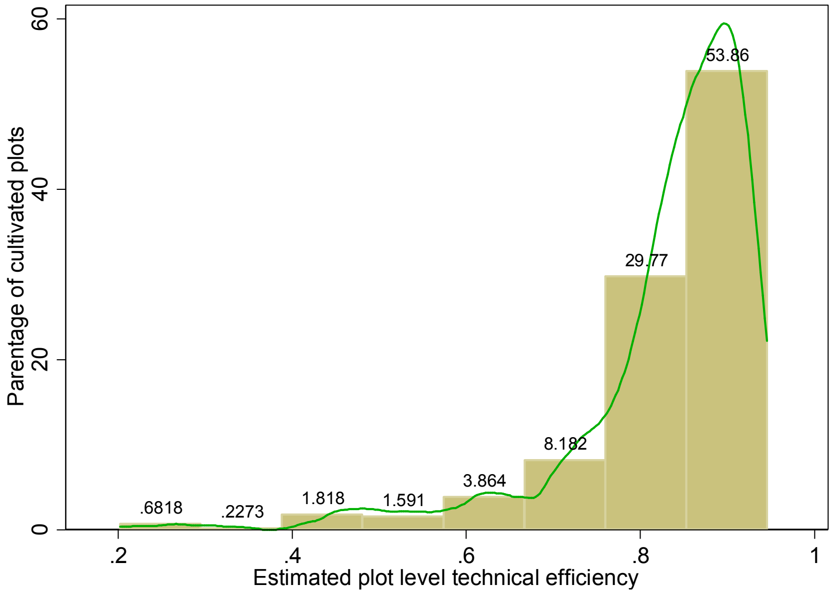

Figure 1. *Distribution of technical efficiency estimates.*

Table 5 presents summary of the estimated plot level maize production TE scores. The TE analysis estimated that average technical efficiency score at which plot level maize production were managed to be 83% with a standard error of 0.11. This means, the average output obtained is only 83% of the potential maximum output from a given mix of production inputs. The distribution of the technical efficiency score rages from 20% to 95% 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 17.0% increase in output by improving technical efficiency with existing technology.

Maize plots in the seven districts considered in the study were operating with mildly different average TE level. For the least operating 25% of the plots the optimum TE level was 83% (Danigela district) while for best operating similar proportion of farms the minimum efficiency level was 84% (Guangua district). The middle 50% of the plots were operating with TE level which ranges from 75% to 89%. The minimum TE level (20%) was registered in Fogera while the maximum (94%) achieved in Merawi/Mecha (Table 5).

Table 5. *Cultivated maize plots grouped by the estimated TE level they were managed.*

District	No. of plots	Mean	Sd	Min	Max	p25	p50	p75
Dangila	96	0.85	0.06	0.60	0.93	0.83	0.86	0.90
Dawa Chefa	36	0.85	0.08	0.59	0.93	0.82	0.88	0.90
Fogera	110	0.79	0.15	0.20	0.95	0.77	0.83	0.88
Gonder Zuriya	40	0.83	0.10	0.47	0.93	0.77	0.85	0.91
Guangua	36	0.71	0.16	0.33	0.92	0.60	0.75	0.84
Merawi/Mecha	98	0.88	0.05	0.64	0.94	0.85	0.89	0.92
Zigam	24	0.85	0.08	0.67	0.94	0.83	0.86	0.91
Total	440	0.83	0.11	0.20	0.95	0.81	0.86	0.90

Source: Own computation (2020).

Estimated actual and potential level of output: The mean levels of the actual and potential output during the production year were 27.01 Qt/ha and 31.82 Qt/ha, with the standard error of 14.19 and 15.18, respectively. Using paired sample t-test, the actual and the potential mean yield were compared and the observed mean deference (4.82Qt/ha) was found significant at 1% level of significance (Table 6). The ratio of the average yield gap to the average actual yield entails the possibility to increase the average plot level output by 17.5% through improving producers TE under the prevailing production input and technology level.

Table 6. *Actual versus potential plot level maize yield.*

Variable	Mean	Std.Dev	Minimum	Maximum
Potential yield (Qt/ha)	31.82	15.18	7.49	110.86
Actual yield (Qt/ha)	27.01	14.49	4.00	96.00
Mean TE	0.83	0.11	0.20	0.95
Yield gap (Qt/ha)	4.82	2.69	0.83	18.93

Source: Own computation (2020).

Estimation of determinants of efficiency model: The focus of this analysis was to provide empirical evidence on the determinants of productivity variability induced by TE difference among smallholder maize farmers in the study area. Merely having knowledge that farmers were technically inefficient might not be useful unless the sources of the inefficiency are identified. Thus, after learning presence of significant TE deference in plot level maize production, the study had tried to identify farm and farmer-specific attributes that had impact TE.

The socio economic and demographic factors, (age, education, household size), resource related factors (number of maize plots, total livestock unit, total farm land size, off farm income, plots soil fertility and improved variety adoption), and contact with extension agents were considered in TE determining analysis. The parameters of the explanatory variables in TE model were estimated using ML and QR methods. The dependent variable of the ML model was inefficiency and the negative signs implied that an increase in the explanatory variable would decrease the corresponding level of inefficiency (i.e., improvement of efficiency), and the positive sign is interpreted inversely. But, the dependent variable in the QR model was TE score and the interpretation for the estimated coefficients is direct. QR analysis was conducted to compare how some percentiles of the TE may be more affected by certain socioeconomic characteristics than other percentiles.

ML and QR (25th, 50th, 75th and 95th quantiles) estimated coefficients of TE model are presented in Table 7. Of the 10 explanatory variables considered in the analysis four variables namely age, education, household size, and number of livestock owned have appeared with unexpected sign. The ML estimate for the coefficients of these variables was statistically insignificant at 10% level of significance. But, the QR estimate household head age have shown it’s negative and statistically significant (at 5%) TE effect across all quantile groups. Household size has also shown similar effect with household head age except for the 95th quantile group. The QR estimates for TE effects of Education and TLU were insignificant at 10% level of significance.

TE effects of the remaining six factors namely, off farm income, improved variety adoption, contact with extension agents and cultivated maize plots soil fertility status was in conformity with the prior economic expectation. Both the ML and QR estimated TE effects of the factors improved variety adoption, contact with extension agents and maize plots soil fertility status were positive and significant at 1% level of significance. The ML estimate for the remaining three factors, off farm income, total cultivated land size and number of cultivated maize plots was insignificant at 10% level of significance. But, the QR estimate for the factors number of maize plots for the 50th, total farm land for 75th and off farm income for the 50th quantile group were significant at 5% level of significance. Those socioeconomic and biophysical factors considered in this study show their statistically significant effect on smallholder maize producers TE level are elaborated in the coming paragraphs.

It is logical to envisage household members as the primary sources of labour for smallholder crop production activities. Based on this premises, household size was expected to influence the TE level at which farmers managed their maize plots positively. The ML estimated for TE effect of household size was insignificant. But, the QR estimate for the 25th, 50th and 75th quartiles were negative and significant at 1% level of significance. As the QR estimate for the 95th quantile shows household size did not affect considerably the performance of farmers who were producing at the higher TE level. One reviewed study has got similar result [13].

In general, improved crop varieties have better yield due to their resistance to various pests and environmental factors. Having to this fact, improved maize variety adoption was expected to have positive effect on the smallholder maize farmers TE level. Both ML and QR estimates for TE effect of improved variety adoption were positive and significant at 1% level of significance. Three reviewed studies conducted in Ethiopia on smallholder maize producers TE have hot got similar result [18, 16, 13].

In principle extension service is a technical support concerning production technologies and ways to improve productivity; hence, it is expected to have positive effect on farmers TE. Increased agricultural extension activities are expected to increase farmers TE by lowering farmers cost of information. Both ML and QR estimates for TE effect of farmers contact with development agents were positive and significant at 1% level of significance. Previous studies conducted in Ethiopia had found similar result [9, 18, and 13]. But, one reviewed study had found negative effect [18] while another study found insignificant effect [11].

It was hypothesized that a smallholder farmer with a greater number of plots in general and maize plots in particular is inefficient than a farmer with more consolidated area. The reason is that as the number of plots operated by the smallholder farmer increases, the smallholder farmer will be unable to distribute labor resources for different activities. The ML estimate for TE effect of number of maize plots cultivated was insignificant while the QR estimate obtained for the 50th quantiles group was positive and significant at 1% level of significance. The result obtained is on the contrary to what was expected. Two reviewed related studies have found somehow similar result [9, 11].

With increased pressure on cropping land, traditional soil fertility regeneration has become less effective. Farmers with no alternatives would therefore be compelled to cultivate on marginal lands which is exposed for serious crop failure incidence. In this study, maize farmers were opted to rate their maize plots fertility status as good, medium and low and only 32% percent of the cultivated plots were rated as good. The ML and QR estimates for output effect of maize plots soil fertility status was found significant at 1% level of significance. As result infers, maize producers TE level was directly related to their maize plots soil fertility status. This means, farmers with more fertile plots were technical efficient as compared to those who cultivate marginal lands, keeping all other factors constant. The result found is in conformity with two similar reviewed national level studies conducted [16] and [11].

Table 7. *Quantile regression and ML estimates of TE determinant model.*

Factors	MLE		Quantile Regression							
			25th		50th		75th		95th	
	Coef.	Z-value	Coef.	Z-value	Coef.	Z-value	Coef.	Z-value	Coef.	Z-value
TLU	0.013	0.49	-0.001	-0.77	-0.001	-1.3	-0.001	-2.4	0.000	-0.62
HHage	0.018	0.94	-0.001	-2.43**	-0.001	-3.32***	-0.001	-3.35**	-0.001	-2.00**
Nplots	-0.159	-0.77	0.007	1.44	0.007	2.74***	0.004	1.81	0.002	0.59
Tfarmland	-0.106	-0.45	0.007	1.15	0.005	1.68	0.010	3.75**	0.009	2.37**
HHSIZE	0.108	1.19	-0.007	-2.85***	-0.006	-4.11**	-0.005	-3.95**	-0.003	-1.78
Educ										
Yes	0.342	0.8	-0.018	-1.78	-0.015	-2.95***	-0.009	-2.08**	-0.008	-1.25
Offincome										
Yes	-0.077	-0.2	0.005	0.52	0.003	0.68	0.009	2.08**	0.009	1.55
Variety										
Improved	-1.581	-2.59**	0.143	13.32***	0.092	16.45***	0.072	15.31**	0.053	8.16***
Extension										
Yes	-1.003	-2.32**	0.090	7.49***	0.061	9.76***	0.038	7.14***	0.034	4.68***
Sfertility										
Medium	1.343	2.5**	-0.095	-9.33***	-0.068	-12.73**	-0.064	-14.27***	-0.054	-8.66***
Low	2.269	2.68***	-0.215	-8.61***	-0.184	-14.02**	-0.164	-14.85***	-0.047	-3.07***
_cons	-2.747	-1.59	0.743	22.76	0.807	47.19	0.843	58.69	0.864	43.4

***, **, * indicate significance at 1, 5 and 10% levels, respectively.
Source: Own computation (2020).

5. Conclusion

The basic objective of the study was to examine the extent of farm specific TE in the use of basic agricultural inputs, and to determine the socioeconomic factors which affects smallholder maize producer's technical efficiency in Amhara region. Stochastic frontier analysis based on translog production function was employed to determine levels of technical efficiency and its determinants analysis was done using both ML and QR techniques.

According to the study result, the average technical efficiency level at which smallholder maize producers operated was 83% percent. This means, on the average producers entertained only 83% of the potential maximum output from a given mix of production inputs. The result, underline the possibility to further increases the output by 17 percent without increasing the levels of inputs. Similarly, the yield gap analysis conducted showed the opportunity to increase the average smallholder's maize producers yield by 4.8qt/ha through improving the current input utilization efficiency to the frontier level.

The study provides sufficient information about the direct relationship maize output has with fertilizer amount and seed use. As per the information obtained, intensifying fertilizer utilization will increase output at least until the fertilizer utilization rate doubles the current level, holding all other factors constant. While intensifying fertilizer use, attention should be given to the factors plot area and seed use as its interaction with them has associated positive and negative effect on output, respectively. Similarly, the study has shown the possibility to increase output through increasing seed rate by small margin from the current utilization level, ceteris paribus. Seed amount interacts with plot area and oxendays with associated positive effect on output. Though ceteris paribus output effects of utilizing additional plot area and labour is insignificant, they affect output via the interaction they made between and among the other production inputs considered.

Improved variety adoption has shown its significant positive effect on the smallholder maize producers TE level. The effect was observed across all TE quantile groups. Farmers adopt improved varieties only when they are perceived as having better characteristics than the local once. Of the sought improved varieties characteristics, yield advantage is most preferred one. The average yield (28.7qt/ha) obtained from plots which received improved varieties was significantly higher than what was obtained (22.4qt/ha) from those plots received local varieties. The result could partly be an outcome of the variation in basic production inputs utilization level. Improved variety adopters have utilized significantly high level of fertilizer and plot area and also, they have used significantly small seed rate as compared to the non-adopters. The amount of oxendays and labour utilized per hectare by the two groups were similar. The result triggered farmers, extension agents, researchers and other stakeholders to work more towards wide adaptation of improved maize varieties with an ultimate goal of improving smallholder maize farmers productivity and hence their wellbeing.

Both ML and QR estimates for TE effect of farmers contact with extension agents were positive and significant. The plot level yield (28.3qt/ha) obtained by farmers who got extension advice was significantly higher than what was obtained (22.0qt/ha) by those farmers who don't entertained extension advise. Of the five production inputs considered, the amount of fertilizer, labour and oxendays utilized by farmers who uses extension service was significantly higher than those producers who don't used extension advice. It is possible to envisage the yield advantage, entertained by maize farmers who used extension advice, as an outcome of relatively higher production inputs utilization which is influenced by the extension advice obtained.

With increased pressure on cropping land, traditional soil fertility regeneration has become less effective. Farmers with no alternatives are compelled to cultivate on marginal lands which is exposed for serious crop failure incidence. In the study, maize farmers were opted to rate their maize plots fertility status as good, medium and low and only 32% percent of the cultivated plots were rated as good. The ML and QR estimates for output effect of maize plots soil fertility status was found significant. As result infers, maize producers TE level was directly related to their maize plots fertility status. This means, farmers with more fertile plots were technical efficient as compared to those who cultivate marginal lands. The result could be considered as signal to strengthen maize plots soil fertility improvement initiatives.

Household members are sources of labor for agricultural activities. The study estimates the average household size in the study area as 6.43 persons which is above the national average rural household size. The QR analysis of smallholder maize producers TE of the 25th, 50th, and 75th quantiles groups were negatively affected by household size as well the associated ML estimate was insignificant. Also output effect of labour estimated for the fitted SFM was insignificant. As the result indicates, the household labour participated in maize production was above employment potential of the activity in the study area. Therefore, improving smallholder maize producers TE level may demand to intensify production activities through incorporating different labour demand tasks which grant better yield and TE if not possible to shift some of the available household labour to other economic enterprises.

On the contrary to prior economic expectation, the total number of maize plots as well size farm land a given household cultivated during the production season has exhibited its significant positive effect on smallholder maize producers TE level for of the 50th, and 75th quantiles groups. The observed positive TE effect might be the due to the availability of excess household labour in mentioned quantile groups. The result infers, the possibility to improve smallholder maize producers TE through farming relatively large number of small plots intensively with better precision when there is excess household labour. On the contrary to the prior economic expectation age of household head and his involvement level in formal education have shown negative and significant effect on the TE level at which maize plots in the 50th and 75th quantile groups were managed.

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