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# Economic efficiency in maize (*Zea mays* L.) production of small holder farmers in Amhara Regional State, Ethiopia

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**Abstract**

*Ethiopian agriculture is explained by low productivity, caused by a combination of demographic economic, constraints, and other factors such as-policy factors, drought, war, lack of basic infrastructure, etc. To improve this problem many of the researchers are focusing only on technical efficiency. So, technical and allocative efficiency are important in improving the productivity gains from existing technology. A multi-stage sampling technique was employed. The study was conducted using cross-sectional data. From 366 households randomly selected. The stochastic frontier function was used to estimate the level of technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE), whereas the Tobit model was used to identify factors affecting efficiency level. The mean TE, AE, and EE were 90.3%, 59.9%, and 76.4%, respectively. The Tobit model results revealed that Gender distance to market, access to credit, training, extension service, seed Variety, and group membership had a significant positive effect on TE, while household size and education level had a negative significant effect on TE. Age, gender, group membership, training, extension service, and seed variety had a positive significant effect on AE, however, household size had a negative significant effect on AE. Moreover, age, gender, group membership, training, extension service, and seed variety had a positive significant effect on EE. However, household size, experience, and distance to market had a negative significant effect on EE. The results showed that there is an opportunity to increase the efficiency of maize production in the study area through improving seed. Therefore, the policies and strategies in development and research may act on these variables to increase the efficiency level of maize producer farmers.*

**Keywords/Phrases**: Cobb-Douglas, Efficiency, Maize, Production, Stochastic frontier, Tobit model

## 1 Introduction

Agriculture is the main economic activity in Ethiopia. According to the United Nations Development Program (UNDP, 2015) two third of the people in developing countries are living in rural areas. Agriculture is the main source of subsistence and income for the majority of the rural people; many of them are small-scale farmers. Farmers in developing countries are depending on farm income and experience a hand-to-mouth way of living. This is because of technological backwardness, rapid population growth, and low productivity of livestock (FAO, 2014).

Agriculture is a dominant sector in Ethiopia that has contributed to the livelihoods of about 85% employed, about 85% labor force, accounts about 45% of the GDP, and for foreign exchange currency about 86% (FDRE, 2016). Accordingly, the government of Ethiopia has taken initiatives that are meant to support achievement, which can be assured by improving efficiency through reducing losses and improving market performance.

Ethiopian agriculture is characterized by low productivity due to technical and socio-economic factors. Mostly, the farmers with the same resources are producing different per hectare output because of management inefficiency inputs, limited use of modern agricultural technologies; obsolete farming techniques, poor complementary services such as extension, credit, marketing, and infrastructure, poor and biased agricultural policies in developing countries like as Ethiopia (WFP, 2012).

Maize is the single most important crop in terms of the number of farmers engaged in cultivation and crop yield, and cereals account for 65 percent of the agricultural value added, equivalent to about 30 percent of the national GDP (Shahidur *et al.*, 2010). The smallholder farmers that comprise about 80 percent of Ethiopia's population are both the primary producers and consumers of maize (Dawit *et al.*, 2008). The role of maize is central to agricultural policy decisions as a prime staple food for food security and the overall development of the agricultural sector. The Ethiopian government has put a lot of effort into promoting agricultural productivity and efficiency of smallholder farmers (Jema, 2008) since agriculture continues to be the dominant sector in Ethiopia's economy. Maize production can increase either through the introduction of modern technologies or by improving the efficiency of inputs with existing technologies. These two are not mutually exclusive because the introduction of modern technology could not bring the expected shift of production frontier if the existing level of efficiency is low. This result implies the need for the integration of modern technologies with improved levels of efficiency (Kinde, 2005).

Economic efficiency in this study refers to the ability of a farmer to produce the maximum possible output at a minimum feasible cost by utilizing the resources they already have most optimally. It encompasses both allocative and technical efficiencies. A proper analysis of the economic efficiency of farmers requires the estimation of both technical and allocative efficiencies. Therefore, this study analyzed the economic efficiency of maize production of smallholder farmers, enhanced efficiency would contribute to improved well-being and sustainable farming for a large segment of Dega Damot *Woreda*, West Gojjam Zone of Amhara Region.

According to previous research in Ethiopia, there also exists a wide cereal yield gap among the farmers that might be attributed to many factors such as lack of knowledge and information on how to use new crop technologies, poor management, climate factors, and others (Sisay *et al.*,2015).

Many of the researchers are focusing only on technical efficiency; understating the benefit that could be derived by producers from the importance of the overall performance of how farmers allocate their resources in response to price incentives, is an important determinant of the profitability of the farming enterprise. So, technical and allocative efficiency are important in improving the productivity gains from existing technology. However, as to the knowledge of the researcher, there is no study done on the economic efficiency of smallholder maize producers in the study area. Hence, there is a need to fill the existing knowledge gap by addressing issues related to technical, allocative, and economic efficiencies of smallholder farmers' maize production in the study area by providing empirical evidence on smallholder resource use efficiency. Therefore, the present study is useful in formulating appropriate policies and research information for reducing the level of economic inefficiency with the objectives of measuring the level of technical, allocative, and economic efficiencies of maize production and identifying factors affecting them in the study area.

Therefore, this study answers the following objectives:

1. To measure the level of economic, technical and allocative efficiency in maize production by small holder farmers in the Dega Damot *Woreda*, West Gojjam Zone.

2. To identify the major determinants that affect efficiencies in maize production in the study area.

## 2 Materials and Methods

### 2.1 Description of the Study Area

Dega Damot is one of the *Woreda*s in the West Gojjam zone, Amhara Region of Ethiopia. It is Part of the Mirab Gojjam Zone, located 399 km away from the capital city of Ethiopia (Addis Ababa). Dega Damot is bordered on the south by Dembecha, on the southwest by Jabi Tehnan, on the west by Kuarit, and the north and east by the Misraq Gojjam Zone. Dega Damot has a population density of 183.27, which is greater than the Zone average of 158.25 persons per square kilometer. A total of 33,336 households were counted in this *Woreda* resulting in an average of 4.57 persons per household and 32,497 housing units. The largest ethnic group reported in Dega Damot is Amhara (99.95%). Amharic is spoken as a first language by 99.97%. The *Woreda* is also characterized by a good climate for most of the year, with annual rainfall between 900 ml and 1200 ml (CSA, 2007). Maize is one of the major staple crops grown in the poorest and most food-insecure regions of Ethiopia, like Dega Damot *Woreda*. The crop is produced under adverse conditions such as low input use and marginal lands. The climate of Dega Damot *Woreda* is most favourable for the cultivation of a wide variety of crops like maize, sorghum, teff, wheat, barley, bean, and pea, oil seeds (vegetable and fruit).

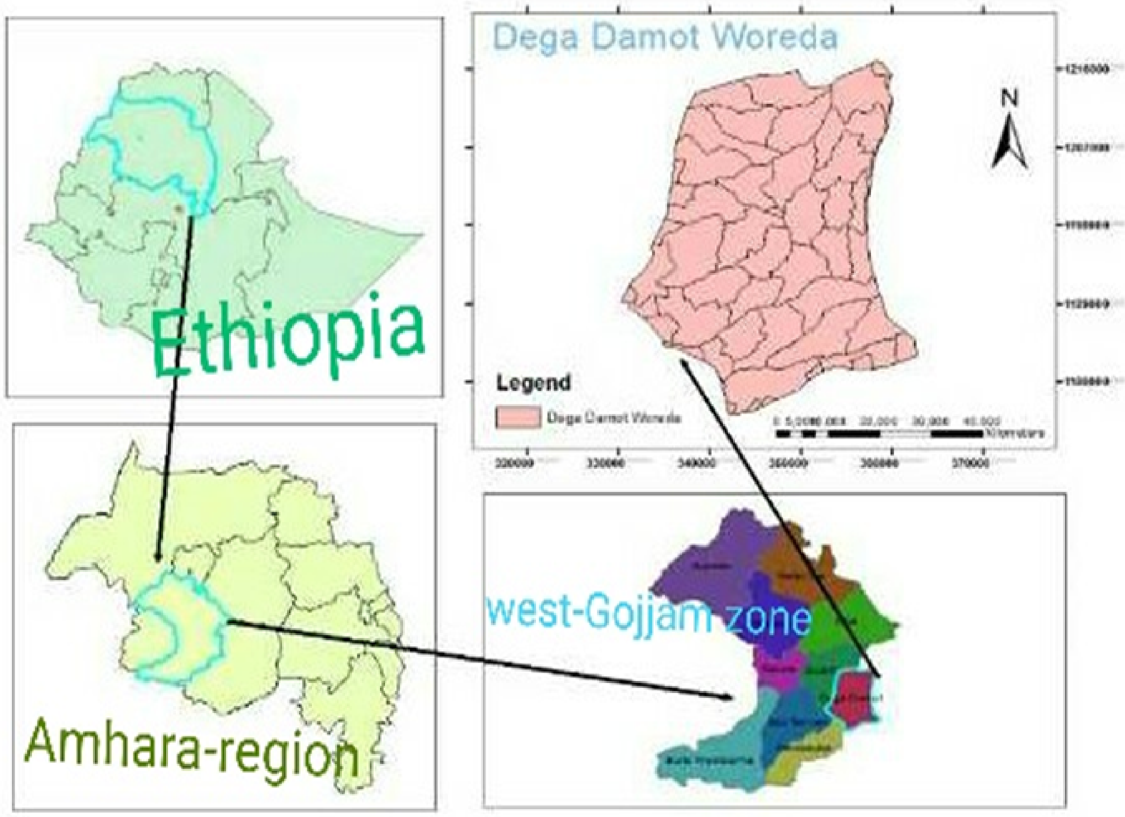


**Figure 1.** Map of the study area (Source: Ethio-GIS, 2018)

## 2.2 Method of Data Collection

Primary and secondary data were used for this study. Primary data was collected from the 2017/18 cropping season using personally administered questionnaires. To collect primary data through structural questionnaires, the study involved 366 respondents. Interviews were conducted to obtain in-depth qualitative information. Structured interviews were conducted with four extension agents, one from each *Kebele*. Through Focus Group Discussion (FGD), this was conducted to obtain individuals' impressions and concerns about maize production. Focus groups allow for interactions between the researcher and the participants and among the participants. The group was composed of four farmers from each *Kebele*.

## 2.3 Sample Size Determination and Sampling Technique

A multi-stage sampling technique was employed to analyze the economic efficiency of smallholder maize producers. In the first stage, Dega Damot *Woreda* was purposively selected for the study because of the presence of a large number of maize-producing households and the extent of maize production in the study area. In the second stage, Dega Damot *Woreda* comprises 32 *Kebeles*. From these, 27 rural *Kebeles* are major maize-producing *Kebeles*. Since the research focuses basically on maize production, maize producer *Kebeles* are the major target areas for the sample selection. In the third stage, out of 27 *Kebeles*, four *Kebeles* are selected randomly due to homogeneity in maize production of all *Kebeles*. Finally, based on the list of households of the *Kebeles* who produced maize during the 2017/18 production year, 366 sample farm households were selected from the total households of four *Kebeles* by using systematic random sampling (SRS) technique based on probability proportional to size (PPS).

### 2.3.1 Sampling Size Determination

According to Dega Damot *Woreda*s agricultural and rural development office, the total household in the four rural *Kebeles* is 4370. The researchers used a formula developed by Yamane (1967) with a precision level of, ±5 (because the target population is homogeneous).

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

Where, $N$ = designates total number of households in four *Kebeles* $n$ = the sample size whom the researcher used $e$ = designates maximum variability or margin of error 5% (0.05).

Thus, $N = 4370$, $e = 0.05$

Therefore, $n = 366$

Based on this approach, a total of 366 farmers from the four *Kebeles* proportional to the size sampling technique were selected. Out of 27 *Kebeles*, 4 rural *Kebeles* were randomly selected, out of which respondents were taken as a sample based on the procedures described below.

**Table 1.** Summarize on Sample size per *Kebele*

| ***Kebele*** | **Maize producing households** | **Sample size ($n$)** |
|---|---|---|
| Geshet Slassie | 1290 | 108 |
| Arefa Debtera | 1242 | 104 |
| Damot Tsion | 1015 | 85 |
| Feresbet Mikael | 823 | 69 |
| Total | 4370 | 366 |

## 2.4 Method of Data Analysis and Interpretation

The data collected from different sources were analyzed using descriptive statistics and econometric methods. The descriptive analysis was used to summarize some important characteristics of the sample households. The descriptive method includes tables, simple ratios, percentages, frequencies, standard deviations, *etc*.

In the econometrics analyses, a stochastic frontier model (SFM) and a two-limit Tobit regression model were used. The purpose of using the econometric method was to estimate the effects of inputs on maize output, to measure the economic efficiency of maize production by using the stochastic frontier production model with maximum likelihood estimation, and factors that affect the economic efficiency of smallholder maize producers by using two-limit Tobit model in Dega Damot *Woreda*. The qualitative data was also summarized and presented to supplement the result of the quantitative analysis. The data was analyzed using the Frontier 4.1c program and STATA software.

### Model Specification and Estimation Procedures

A stochastic frontier production model proposed by Battese and Coelli (1995) by the original models for Aigner, *et al*. (1977) and Meesuen and van den Broeck (1977) was applied to cross-sectional data to estimate the effects of input on maize output using maximum likelihood estimation. In this study, the stochastic production function was used for its key features that the disturbance term is composed of two parts *i.e.*, a two-sided and symmetric term and a one-sided component.

### Cobb-Douglas stochastic frontier production function Model

Either a Cobb-Douglas (CD) or Translog (TL) functional form for the production functions. In this study, only CD model was specified and the most appropriate model is selected based on log-likelihood ratio tests.

For Cobb-Douglas production function defined over $N$ inputs,

$$Y = AX_1^{\beta_1} X_2^{\beta_2} ......XN^{\beta_N}$$

Where, $Y$ = yield of maize and $X_i$ = different variable of inputs ($i$ = 1, 2, 3, ..., $N$)

The measure of returns to scale, RTS, representing the percentage change in output due to a proportional change in use of all inputs, is estimated as the sum of output elasticities for all inputs.

The specific Cobb-Douglas production model estimated is given.

$$Y_i = \beta_0 * \prod_{i=1}^{n} X_i \beta_i * e^{(v_i - u_i)}$$

By transforming it into double log-linear form

$$lnY_i = ln\beta_0 + \sum_{i=1}^{5} lnX_i + (V_i - U_i)$$

Where, $Y_i$ represents maize yield harvested and $X_i$ represents maize inputs by $i^{th}$ farmer (Land, Oxen, Seed and Fertilizer). Whereas $\beta_0$, $\beta_1$, $\beta_2$, $\beta_3$, $\beta_4$, and $\beta_5$ the regression parameters to be estimated and ln= natural logarithm. From the error term component ($V_i$ – $U_i$), $V_i$ is a two sided ($-\infty <$V$< \infty$) normally distributed random error ($v \sim N$ [0, $\sigma^2 v$]) that represents the stochastic effects outside the farmer's control (e.g., weather, natural disasters, and luck), measurement errors, and other statistical noise while Ui is a one-sided ($u_i \geq 0$) efficiency component which is independent of vi and is normally distributed with zero mean and a constant variance ($\sigma^2 u$) allowing the actual production to fall below the frontier but without attributing all short falls in output from the frontier as inefficiency.

**Stochastic frontier Cobb-Douglas cost function**

In order to estimate farm level overall economic efficiency, the stochastic frontier cost functions model is specified as follows:

$$C_i = h\ (Y_i, P_i, \alpha_i) + \varepsilon_i$$

Where, $C_i$ is the total production cost, $Y_i$ stands for output produced, $P_i$ is price of input, $\alpha_i$ represents the parameters of the cost function to be estimated and $\varepsilon_i$ is the error term. Since, inefficiencies are assumed to add to costs, error components, therefore, have positive signs.

**Tobit Model with Maximum Likelihood Estimation**

The estimation of the Tobit Model is the censored regression model, also called the Tobit model, to pay respect to Tobin (1958), who was the first to introduce censoring in economics. The most common censored regression model is the Tobit model, which expresses the observed level in terms of an underlying latent variable. A Tobit is a censored regression model in which the dependent variable is observed only if it is above or below some cut-off level. A two-limit Tobit model is a censored normal regression model where the dependent variable is continuous, and its range is constrained both from above and below by cut-off point.

The dependent variable lies in a double-bounded range (*i.e.*, between zero and one). The use of the Tobit model is intuitive because the parameter estimates are biased and inconsistent if OLS is used (Gujarati, 2004). In the model the dependent variables are economic efficiency (technical and allocative efficiency) scores which will be regressed against the common independent variables (age of the household head, experience in maize production, education, gender, household size, access to credit, distance to market, extension service, group membership, family income training and seed varieties). A number of explanatory variables were expected to influence the economic efficiency (technical and allocative efficiencies) directly or indirectly.

In measuring the factors affecting economic efficiency levels, a two–limit Tobit regression model was used. The estimated efficiency scores were regressed on a set of socio-economic, institutional, demographical, and other factors that were assumed to be important determinants of efficiency. The Tobit regression model was considered more appropriate since the values of the dependent variables (efficiency scores) lay within a certain interval (0, 1).

Three separate equations for determinants of technical, allocative, and economic efficiency were estimated using a two-limit Tobit model with the dependent variable as the technical, allocative, and economic efficiency indices, respectively. Following Amemiya (1981), Waluse (2011), Essa *et al.* (2011), and Endrias *et al.* (2013), the two-limit tobit model was defined as:

$$Y_i\text{*EE, TE, AE} = \beta_0 + \sum_{j=1}^{12} \beta_i Z_{ij} + U_i$$

Where *Yi** is the latent variable representing the efficiency scores, $\beta_0$, $\beta_1$, ..., $\beta_{12}$ are parameters to be estimated, and EE, TE, and AE are economic, technical and allocative efficiency of the $i^{th}$ farmer, respectively. $Z_i$ is demographic, socioeconomic and institutional factors that affect efficiency level. And, $\mu_i$ is an error term that is independently and normally distributed with mean zero and variance $\sigma^2$ ($\mu_i \sim$ IN 0, $\sigma^2$).

### 2.5 Diagnostic Tests

#### 2.6.1. Test for Heteroskedasticity

Heteroscedasticity Test is a situation in which the assumption of equal variance of residuals in the classical linear regression model is violated. In this situation, the estimators are unbiased but inefficient, and the estimates of the variances are biased, leading to invalid tests of significance results (Maddala, 1992). The first step in addressing the problem of heteroscedasticity is to determine whether or not heteroscedasticity exists. There exist several tests for heteroscedasticity detection, among others, the Koeker Basset, the PBPG, the White's, and the Breusch-Pagan tests as listed by Gujarati (2004). A test for heteroskedasticity was done to verify the assumption of constant variance. The Breusch-Pagan /Cook-Weisberg test for heteroscedasticity was used. To correct for heteroscedasticity, the robust option was used in the MLE regressions for both models (Baum, 2006).

#### 2.6.2 Multicollinearity

The data was also tested for multicollinearity. Test for the presence of multicollinearity in the models was performed using the Variance Inflation Factor (VIF). Multicollinearity is a situation when the independent variables are highly inter-correlated.

According to Gujarati (2004), the value of VIF more than ten is usually considered an indicator of serious multicollinearity and should be excluded from the model. The multicollinearity test for both continuous and dummy variables at the same time was done using the Variance Inflation Factor (VIF) to check the multicollinearity problem among all variables entered in the model. In addition, multicollinearity tests of continuous and dummy variables were checked using the variance inflation factor and contingency coefficient, respectively.

## 3 Result and Discussion

### 3.1 Estimating the Result of the Production and Cost Function

The maximum likelihood estimates (MLE) of the parameters of the stochastic frontier production function for maize farmers are presented in Table 1. The values of output Elasticity of all input variables are positive and have a significant influence on maize output growth except Labour. This suggests that as labour increases, maize production decreases. This result could mean that using more labour on a fixed size of land might lead to labour redundancy and a labour surplus whose withdrawal would leave output virtually unchanged.

**Fertilizer** (chemical and organic) is a major land augmenting input that improves the productivity of existing land by increasing yield per unit area. The coefficient of fertilizer used by farmers has a positive relationship with maize output and is significant at a 1% level. It is indicated that a 1% increase in the amount of fertilizer in kg would increase maize yield by (11.1%). Other input remains constant. This type of relationship is, however, expected where the available fertilizer is efficiently applied in terms of rate along with other inputs to avoid diminishing return to fertilizer. This result is consistent with the findings of Netabirabose (2017). Fertilize had a positive impact on productivity and was statistically significant at 1% and 5% level;

**Table 2.** The Maximum Likelihood Estimates of the Cobb-Douglas Stochastic Frontier Production Function

| Variable | Parameter | Coefficients | Std. Error | Z | *p*-value |
|---|---|---|---|---|---|
| **Constant** | $\beta_0$ | 5.45 | 0.187 | 29.19 | 0.000 |
| ln(land) | $\beta_1$ | .244 | 0.0858 | 2.84 | 0.005 |
| ln(labor) | $\beta_2$ | 0.0163 | 0.0684 | -0.24 | 0.811 |
| ln(seed) | $\beta_3$ | 0.103 | 0.046 | 2.27 | 0.023 |
| ln(oxen) | $\beta_4$ | 0.219 | 0.086 | 2.55 | 0.011 |
| ln(fertilizer) | $\beta_5$ | 0.111 | 0.036 | 3.09 | 0.002 |
| $\ln\sigma^2 v$ | | -3.737 | 0.211 | -17.83 | 0.000 |
| $\ln\sigma^2 u$ | | -4.086 | 0.784 | -5.21 | 0.000 |
| $\sigma v$ | | 0.153 | 0.016 | | |
| $\sigma u$ | | 0.130 | 0.051 | | |
| $\sigma^2$ | | 0.040 | 0.009 | | |
| $\lambda$ (lambda) | | 0.848 | 0.066 | | |
| $\gamma$ (gamma) | | 0.522 | | | |

Note: *, **, *** significant at 10%, 5% and 1% level of significance, respectively

**Land** (farm size) is another variable worth mentioning. The coefficient of land was also found to be positive and significant at a 1% level. The highest coefficient of output to land (24.4%) indicated that land is the main determinant of maize production in the study area. Maize production is relatively sensitive to land. This implies that a one percent increase in farm size used in hectare increases the maize output by about (0.244) percent while other inputs remain constant. This implies the 1% statistical significance level for farm size also implies that the influence of changes in farm size on production efficiency was very important. This means that there is scope for increasing output by expanding farm size. This result is similar to the findings of Tarekegn (2017), who revealed farm size to be significantly related to cumin output.

**Oxen**: in most developing countries like Ethiopia, oxen are the main source of draft power to perform activities like ploughing and sowing crops. The estimated coefficient of oxen days (one oxen-day is equivalent to eight working hours) was found to be positive and significant at the 5 level. The positive sign implies that using more ploughs can increase the output of maize. As a result, a 1 percent increase in the number of oxen per day will result in a (21.9%) percent increase in the maize output, keeping other inputs constant. This finding is consistent with the study of Getachew (2017) and Bealu *et al.* (2013).

**Seed**: seed also showed a positive effect on maize productivity according to the findings and significance at a 5% level. As a result, other things kept constant, a 1% increase in seed amount in kg will lead to a (10.3%) % increase in maize output. Hence, it might be better to use improved and certified maize seeds to increase their maize output. This finding is consistent with the study of Bealu *et al.* (2013) and Tarekegn (2017) seed is the most vital input for crop production.

Wald $Chi-square$ statistic = 752.41 and Probability = 0.000, since the Wald $Chi-square$ statistic is significant at 1% level, we reject the null hypothesis that there is the absence of inefficiency in favour of the presence of inefficiency. To check whether technical inefficiency effects are absent, we may use the important test, and the important parameter of log-likelihood in the half-normal model is $\lambda$ = $\sigma$u/$\sigma$v. If the value of $\lambda$ is equal to 0, there are no technical inefficiency effects, and all deviations from the frontier are due to noise (Aigner, Lovell, & Schmidt, 1977). The estimated value of $\lambda$=0.848 is significantly different from 0, and the null hypothesis that there are no inefficiency effects is rejected at a 1%

significance level.

The results of Maximum Likelihood estimates of variance parameters explain that the variance parameter gamma ($\gamma$) is the ratio of variance of farm-specific technical efficiency to the total variance of output and has a value between zero and one.

$$\gamma = \frac{\sigma^2 u}{\sigma^2 u + \sigma^2 v} = 0.522$$

Therefore, it can be concluded that there is inefficiency in the production of maize. The estimated value of $\gamma$ was 0.52, which indicated that about 52% of total variation in maize farm output was due to technical inefficiency. Thus, 52% of the variation in composite error term was due to the inefficiency component. This result also suggests that about 48% of the variation was due to random shocks outside the farmer's control. For instance, weather conditions/temperature during the maize production process. If technical inefficiencies among maize producers are minimized, there can be optimization of maize output.

### 3.2 Efficiency Scores

Frontier version 4.1c computer program was used to estimate technical efficiency (TE) and cost efficiency (CE). Cost efficiency is the ratio of observed cost to the optimum cost.

**Table 3.** Summary Statistics of Efficiency Measures

| Types of efficiency | Min | Max | Mean | Std. deviation |
|---|---|---|---|---|
| TE | 0.755 | 0.963 | 0.903 | 0.342 |
| AE | 0.309 | 0.826 | 0.599 | 0.865 |
| EE | 0.526 | 0.909 | 0.764 | 0.120 |

TE (Technical efficiency), AE (Allocative efficiency), and EE (Economic efficiency)

Accordingly, cost efficiency will always range from 1 to infinity, while technical, allocative, and economic efficiency will always be bounded between 0 and 1. But to keep the discussion in line with technical efficiency from the production function and cost efficiency from the cost function, calculate economic efficiency to take the inverse of cost efficiency allocative efficiency obtained from technical and economic efficiencies is estimated as follows: AE = EE/TE. After estimating the stochastic frontier production and cost functions, respectively. The mean scores of technical, economic, and allocative efficiency from the sample farm of Dega Damot *Woreda* were 90.3%, 76.4%, & 59.9%, respectively. The minimum technical, allocative, and economic efficiency scores for the sampled farms were 0.755 %, 0.309%; & 0.526 %, respectively. The maximum allocative technical and economic efficiency scores for the sampled farms were 96.3%, 82.6%, & 90.9%, respectively.

### 3.3 Determinants of Efficiency among Maize Producers in the *Woreda*

In measuring the factors affecting economic efficiency levels, a Two–limit Tobit regression model was used. The estimated efficiency scores were regressed on a set of socioeconomic, institutional demographical, and factors that were assumed to be important determinants of efficiency. The major interest behind measuring TE, AE, and EE levels is to know what factors determine the efficiency level of individual farm households and to come up with development and policy recommendations that improve their efficiency. The TE, AE, and EE scores derived from the model were regressed on socioeconomic, demographic, and institutional variables that explain variations in inefficiency across farm households using the Tobit regression model.

#### 3.3.1. Determinants of Technical Efficiency

According to Table 4, the result shows that estimates from a tobit regression of socio-economical, demographical, and institutional factors effect of technical efficiency scores in the study area. The variables were found to be Age, gender, education level, experience, household size, group membership, training, distance to market, extension service, access to credit, family income, and seed variety.

**Table 4.** Two–limit Tobit model technical efficiency result

| | | Robust | | |
|---|---|---|---|---|
| **Technical efficiency** | **Coefficient** | **Standard error** | *t* | *P* >\|t\| |
| **Constant** | 0.866 | 0.0103 | 83.67 | 0.000 |
| age | 0.00014 | 0.0003 | 0.49 | 0.625 |
| gender | 0 .0121 | 0.0037 | 3.25 | 0.001 |
| education | -0.0046 | 0.0016 | -2.90 | 0.004 |
| hhsize | -0.0014 | 0.00080 | -1.71 | 0.088 |
| famincome | 3.98e-07 | 3.61e-07 | 1.10 | 0.271 |
| experience | -0.00035 | 0.00040 | -0.87 | 0.387 |
| dismarket | 0.00045 | 0.00015 | 2.99 | 0.003 |
| acccredit | 0.0229 | 0.0030 | 7.53 | 0.000 |
| groupmm | 0.0106 | 0.0030 | 3.51 | 0.001 |
| training | 0.0079 | 0.0030 | 2.63 | 0.009 |
| extsservice | 0.008 | 0.0029 | 2.56 | 0.011 |
| seedvariety | 0.009 | 0.0036 | 2.57 | 0.011 |
| Number of obs = | 366 | | | |
| LR $Chi^2$ (12) = | 242.49 | | | |
| Prob > $Chi^2$ = | 0.0000 | | | |
| Log likelihood = | 833.19002 | | | |
| Pseudo $R^2$ = | -0.1703 | | | |

Note: significant at 10%, 5% and 1% level significance, respectively

According to this study, the Tobit model is results for each significant variable are discussed as follows:

The gender of the household head showed a positive effect on the technical efficiency (TE) of the maize farms and was found to be significant at a 1% level. From the marginal effect result, the result shows that the sex of the household head from (0=F, 1=M) increases the probability of technical efficiency of farmers by about 1.2 percent. It also implies that male-headed households are more technically efficient than female-headed households. The possible explanation is that male household heads might have better practical experiences in farming. Also, one might argue that female household heads are too occupied with domestic activities and have little time for the management of their maize plots, which leads to low technical efficiency levels. This result is consistent with the findings of Muluken (2014).

**Group membership**: Technical efficiency was also influenced by a maize farmer who participated in a producer cooperative/group. Due to this finding, group membership of the household head showed a positive effect on the technical efficiency (TE) of the maize farms and was found to be significant at a 1% level. From the marginal effect result, an increase in group membership to farmers' cooperatives also increases the probability of technical efficiency. Farmers who were members of farmers' cooperatives improved their technical efficiency levels by 1.057 percent compared to those who failed to join farmer groups, assuming that other variables are kept constant. This result is consistent with the findings of Bealu, *et al.* (2013).

**Distance to market**: theoretical distance to market is hypothesized that the distance of maize production to the market was negatively related to technical efficiency. Households located nearer to the factor markets showed higher technical efficiency than those located in remote areas. However, the findings of the unexpected result were distance to the market of the household head showed a positive effect on the technical efficiency (TE) of the maize farms and was found to be significant at a 1% level.

From the marginal effect result, an increase in the distance to the market by one kilometre leads to an increase in the farmer's probability of technical efficiency by about 0.045 percent, with other variables being constant. Therefore, farmers have to get inputs easily and communication channels have to be improved to get a better level of technical efficiency. This result is in disagreement with Ntabakirabose (2017) and Bealu *et al.* (2013) that this finding was negatively related and significantly affected technical efficiency.

**Access to credit** is an important element in agricultural production systems. It allows the producer to satisfy their cash needs induced by the production cycle. The amount of credit increases farmers' efficiency because it temporarily solves the shortage of liquidity/working capital. In this study, the amount of credit was hypothesized in such a way that farmers who get more amount of credit at the given production season from either formal or informal sources were expected to be more efficient than those who get less amount of credit. In the study access to credit in the household head showed a positive effect on technical efficiency (TE) of the maize farms and was found to be significant at a 1% level. From the marginal effect result, According to the findings, a household head having access to credit increases the probability of technical efficiency by about 0.75%. This result is consistent with the findings of Netabirbose (2017) and Musa *et al.* (2014).

**Training**: Training is an essential tool in building the managerial capacity of the household head. Household heads that get training related to crop production and marketing or any related agricultural training are hypothesized to be more efficient than those who did not receive training. Training farmers on maize crops was essential because it could improve farmers' skills regarding production practices and related aspects. Several farmers in the study areas received training on maize for a few days mainly on production practices and the importance of using improved packages. Due to the findings, training of the household head showed a positive effect on the technical efficiency (TE) of the maize farms and was significant at a 1% level. From the marginal effect result, an increase in the number of farmers who attended training in maize production increases the probability of technical efficiency of farmers by about 0.79 percent than farmers who did not attend it. This result implies that farmers with training were technically more efficient than farmers without training. This result is consistent with the findings of Netabirbose (2017 and Bealu *et al.*, (2013).

**Seed variety**: The seed variety of the household head showed a positive effect on the technical efficiency (TE) of the maize farms and was significant at a 1% level. From the marginal effect result, Farmers using improved seed Varieties of the household head increased the probability of the technical efficiency of the farmers by about 0.91%; other variables were kept constant. Farmers who used improved seed at least on one of their plots are technically more efficient than others. Seed variety is a dummy variable that represents whether the farmer adopted improved seed practice. It was hypothesized that farmers who practiced seed variety could be more efficient than their counterparts, as it helps to increase output by improving seed verity required for maize production and may result in a reduction in costs. This result is consistent with findings of Bealu, *et al*, (2013).

Education level of the household head showed a negative effect on the technical efficiency (TE) of the maize farms in the study area and it was significant at a 1% level. From the marginal effect result, as years spent in school increased, the probability of technical efficiency of farmers decreased by 0.45%, and other variables remained constant. This result is consistent with the findings of Getachew, *et al.* (2017). According to the result reported by Alemu *et al.* (2009), education decreases efficiency. The argument is as the level of a farmer's education increases, he or she may get better opportunities outside the farming sector. Ultimately, this reduces labor availability for maize production in the household thereby lowering efficiency. And Adesina and Djato (1996) have views on the effect of education on efficiency. They contend that educated farmers may not necessarily be more efficient than uneducated farmers since uneducated farmers may have acquired more farming experience and knowledge than their educated counterparts and may be more efficient technically. Contrary to these arguments, evidence from Battesse and Coelli (1995) shows that education enhances the ability to utilize available technology and increases the efficiency of farmers. These studies reported are unexpected result of a negative relationship between technical efficiency and education.

This result is in disagreement with the findings of Mustefa *et al.* (2014), Muluken (2014), and Bealu *et al.* (2013). This study showed positive and significant impact of education on all types of efficiencies. It confirmed the importance of education in increasing the efficiency of production. It is a variable that is expected to increase managerial ability and lead to good decisions in farming. Because of their better skills, access to information, and good farm planning, literate farmers are better able to manage their farm resources and agricultural activities and are willing to adopt improved production technologies than illiterate ones.

**Household size** (family size) of the household head showed a negative effect on the technical efficiency (TE) of the maize farms in the study area, and it was significant at a 10% level. From the marginal effect result, a one-person increase in household size would decrease the probability of technical efficiency of farmers by about 0.14 percent, with other variables being constant. This result was due to households with large numbers of family members were not able to use appropriate input combinations due to a shortage of cash. Musa *et al.* (2014), Essilfie *et al.* (2011), and Belete *et al.* (2014) also had similar findings, and their argument was based on the fact that large household size increases the population pressure on the farmer's limited resources due to increases in household spending.

**Extension service** affected technical efficiency level positively and significantly at 1% level. From the marginal effect result, Maize farmers who accessed extension services pointed out a higher level of technical efficiency by 0.75% than those who failed to access the services. Other variables are kept constant. The positive estimated coefficient for contact with extension workers implies that efficiency increases with the number of visits made to the farm household by extension workers. Extension services reveal that farmers, who have access to extension services, have implemented relatively more crop diversification than those who did not have access to extension services. Extension workers have technical knowledge of crop production and improved production management practices that can assist farmers in implementing their crop diversification decisions. Therefore, appropriate and adequate extension services should be provided. This result is consistent with the findings of Ahmed *et al.* (2013, Netabirbose (2017, Desale (2017), Daniel (2016), and Bealu *et al.* (2013).

### 3.4 Determinants of Allocative Efficiency

According to table 5 result shows that estimates from a tobit regression of socio-economical, demographical and institutional factors effects of allocative efficiency scores in the study area.

According to the results, nine in twelve variables were found to have a significant contribution to allocative efficiency. Allocative efficiency as mentioned earlier is another important part of the total productivity of farms. Optimal use and allocation of inputs may potentially be an aspect that could improve the overall productivity of farms.

Gender of the household head showed a positive effect on the allocative efficiency (AE) of the maize farms and was found to be significant at a 1% level. From the marginal effect result, the result shows that the sex of the household head from (0=F, 1=M) increased the probability of allocative efficiency of farmers by about 3.57% when other factors were kept constant. It also implies that male-headed households are more allocative efficient than female-headed households. This may be because allocative efficiency requires greater knowledge and skill gathered over time, which increases the capacity of farmers for optimal allocation of resources and technology.

**Table 5.** Two–limit Tobit model Allocative efficiency result

| Allocative efficiency | Coefficient | Robust Standard error | *t* | *P* >\|t\| |
|---|---|---|---|---|
| **Constant** | 0. 4245 | 0.0410 | 10.34 | 0.000 |
| age | 0.00295 | 0.00112 | 2.63 | 0.009 |
| gender | 0.03578 | 0.0146 | 2.45 | 0.015 |
| education | -0.01065 | 0.00709 | -1.50 | 0.134 |
| hhsize | -0.0061 | 0.0030 | -2.06 | 0.040 |
| famincome | 2.90e-06 | 1.22e-06 | 2.38 | 0.018 |
| experience | -0.0035 | 0.0016 | -2.22 | 0.027 |
| dismarket | -0.00102 | 0.00073 | -1.41 | 0.159 |
| acccredit | -0.01145 | 0.013 | -0.88 | 0.379 |
| groupmm | 0.0517 | 0.013 | 3.84 | 0.000 |
| training | 0.0553 | 0.012 | 4.49 | 0.000 |
| extservice | 0.03108 | 0.013 | 2.45 | 0.015 |
| seedvariety | 0.0463 | 0.014 | 3.35 | 0.001 |
| Number of obs = | 366 | | | |
| R $Chi^2$ (12) = | 153.53 | | | |
| Prob > $Chi^2$ = | 0.0000 | | | |
| Log likelihood = | 326.92949 | | | |
| Pseudo $R^2$ = | -0.3068 | | | |

The age of the household head showed a positive effect on the allocative efficiency (AE) of the maize farms and was significant at a 5% level. According to the marginal effect result, as the age of the household head increased by a year, the probability of allocative efficiency increased by 0.30%, when other factors were kept constant. This indicates that the older farmers are more efficient than the younger ones. This may be because allocative efficiency requires knowledge and skill gathered over time, which increases the capacity of farmers for optimal allocation of resources and technology. This suggested that older farmers were more efficient than their young counterparts. The reason for this may probably be that the farmers become more skillful as they grow older due to cumulative farming experiences. This is consistent with the findings of Daniel (2016).

Family income of the household head showed a positive effect on the allocative efficiency (AE) of the maize farms and was significant at a 5% level. From the marginal effect result, a unit increase in the family income owned by a household increased the probability of allocative efficiency by about 0.00029 percent when other variables were kept constant. As these family incomes increase positively, the efficiency of farmers improves. This result is because the availability of family income shifts the cash constraint outwards and enables farmers to make timely purchases of those inputs that they cannot provide from on-farm income. Therefore, it enables farmers to maximize their output by allocating efficiently at an efficient cost of production. The result is in line with the findings of Hasen (2011), Abebayehu (2011), and Mustefa (2014).

**Household size** (family size) of the household head showed a negative effect on the allocative efficiency (AE) of the maize farms in the study area, and it was significant at a 5% level. From the marginal effect result, a one-person increase in household size would decrease the probability of allocative efficiency of farmers by about 0.61 percent when other variables are constant. This might be because farmers with large family sizes had less good capacity for optimal allocation of resources. This result is consistent with the findings of Daniel (2016) and Hika (2016).

Group membership of the household head showed a positive effect on the allocative efficiency (AE) of the maize farms in the study area, and it was significant at a 1% level. From the marginal effect result, Farmers who were members of farmers' co-operatives improved their allocative efficiency levels by 5.16 percent compared to those who failed to join farmer groups, assuming that other variables are kept constant. Theoretically, membership in social organizations helps producers in achieving efficiency. This result is consistent with the findings of Waluse (2012) and Bealu (2013).

Extension service was also found to affect allocative efficiency (AE) level positively and significantly at a 5% level. From the marginal effect result, According to the findings, maize farmers who accessed extension services pointed out a higher level of probability of allocative efficiency by 3.11% than those who failed to access the services. Besides, the frequency of extension contact was an important factor that affected the allocative efficiency of farmers in the study area. This result was due to new skills and information farmers learned from development agents. This result is consistent with the findings of Mustefa (2014), Tarekegn (2017), Desale (2017), Daniel (2016), and Bealu (2013). From the marginal effect result, increasing extension contact by a single day increases the possibility of maize market participation by 0.47%.

Experience: The effect of farming experience, usually measured in the number of years the farmer has been involved in maize farming, is one of the socio-economic factors that has been given greater attention in many stochastic production function literature. Experience significantly affected the allocative efficiency (AE) of the sampled households at a 5% level of significance. From the marginal effect result, as the farming experience increased by one year, the probability of allocative efficiency of farmers decreased by 0.34 when other factors were kept constant. However, the sign of the coefficient for allocative efficiency is negative and contradictory to the expectation. Its negative sign might be due to farmers having more experience in farming may not be responsive to modern input combinations that minimize their costs.

Farmers with many years of production experience have higher capital accumulation than those farmers who have little experience. Therefore, once the farmer accumulates capital, the desire for farming might be weak, and he will shift to other business activities instead. So, this might lead to decreasing efficiency of smallholder farmers in maize production. This result is in line with the earlier research findings of Getachew (2017), Musemwa *et al* (2013), Hika (2016), and Gosa (2014).

Training of the household head showed a positive effect on the allocative efficiency (AE) of the maize farms and was significant at a 1% level. From the marginal effect result, an increase in the number of farmers who attended training in maize production increases the probability of allocative efficiency of farmers by about 5.53 percent than farmers who did not. It can be concluded that training enabled them to use inputs in a cost-minimizing input ratio. This result is in line with the finding of Nejuma (2012).

Seed verity of the household head showed a positive effect on allocative efficiency (AE) of the maize farms and was significant at a 1% level. From the marginal effect result, farmers using improved seed variety of the household head increase the probability of the allocative efficiency of the farmers by about 4.63% when other variables remain constant. This result is consistent with the findings of Bealu *et al*, (2013). The use of improved seeds will also increase efficiency.

### 3.5 Determinants of Economic Efficiency

According to the results, ten in twelve variables were found to have a significant contribution to economic efficiency.

Gender of the household head showed a positive effect on the economic efficiency (EE) of the maize farms and was significant at a 1% level. The marginal effect result shows the sex of the household head from (0=F, 1=M) increases the probability of economic efficiency of farmers by about 4.36 percent. Male-headed farm households were more likely to make market-oriented decisions than female-headed households. This result was because female-headed households were exposed to resource constraints for crop production.

**Table 6.** Two–limit Tobit model economic efficiency result

| Economic efficiency | Coefficient | Robust Standard error | $t$ | $P>\|t\|$ |
|---|---|---|---|---|
| **Constant** | 0.6345 | 0.0279 | 22.70 | 0.000 |
| age | 0.00224 | 0.00081 | 2.75 | 0.006 |
| gender | 0.0437 | 0.1028 | 4.26 | 0.000 |
| education | -0.00625 | 0.0048 | -1.31 | 0.192 |
| hhsize | -0.0043 | 0.0021 | -2.09 | 0.037 |
| famincome | 1.89e-06 | 8.50e-07 | 2.23 | 0.027 |
| experience | -0.00338 | 0.00108 | -3.11 | 0.002 |
| dismarket | -0.0011 | 0.00049 | -2.22 | 0.027 |
| acccredit | -0.0118 | 0.0087 | -1.35 | 0.177 |
| groupmm | 0.0385 | 0.0090 | 4.23 | 0.000 |
| training | 0.0433 | 0.0084 | 5.13 | 0.000 |
| extservice | 0.0285 | 0.0086 | 3.32 | 0.001 |
| seedvariety | 0.03079 | 0.0092 | 3.32 | 0.001 |
| Number of obs = | 366 | | | |
| LR $Chi^2$ (12) = | 196.34 | | | |
| Prob > $Chi^2$ = | 0.0000 | | | |
| Log likelihood = | 450.24502 | | | |
| Pseudo $R^2$ = | -0.2788 | | | |

The age of the household head showed a positive effect on the economic efficiency (EE) of the maize farms and was significant at a 1% level. From the marginal effect result, an increase in the farmer's age by one year increases the level of probability of economic efficiency by 0.22% when other variables were kept constant. Therefore, the older farmers are the more economically efficient. The results show that the aged head of household is more efficient and produces the output efficiently. This result ensured that aged households have more experience and use their past learning in the production process to produce more output with a given level of inputs efficiently. This result is consistent with the findings of Tarekegn (2017) and Nejuma (2012).

Family income of the household head showed a positive effect on the economic efficiency (EE) of the maize farms and was significant at a 5% level. From the marginal effect result, a unit increase in the family income owned by a household increased the probability of economic efficiency by about 0.0002 percent when other variables were kept constant. The result was consistent with Solomon (2014).

Household size (family size) of the household head showed a negative effect on the economic efficiency (EE) of the maize farms in the study area, and it was significant at a 5% level. From the marginal effect result, one person increases the household size of a household head and decreases the probability of economic efficiency by about 0.43 percent when other variables were kept constant. Household size is an unexpected sign in economic efficiency; a possible reason for the expected might be that a larger household size guarantees the availability of family labor for farm operations to be accomplished in time. At the time of peak seasons, there is a shortage of labour, and hence households with large family sizes would deploy more labour to undertake the necessary farming activities, like ploughing, weeding, and harvesting on time than their counterparts and hence, they are more efficient in maize production.

Group membership of the household head showed a positive effect on the economic efficiency (EE) of the maize farms in the study area, and it was significant at a 1% level. From the marginal effect result, Farmers who were members of farmers' cooperatives increased the probability of economic efficiency of farmers by about 3.84 percent compared to those who failed to join farmer groups, keeping other variables constant.

Farmer membership in farmer cooperatives is used as a proxy for measuring the role of social organization in the production process. Farmers who are members of farmer cooperatives receive more viable information on production technologies than farmers who are not. As a result, they experiment and apply new production technologies, and hence, they are more efficient in maize production. This result is consistent with the findings of Waluse (2012) and Bealu (2013).

Extension service was also found to affect economic efficiency (EE) level positively and significantly at the 1% level. From the marginal effect result, according to the findings, maize farmers who accessed extension services pointed out a higher probability of economic efficiency by 2.85% than those who failed to access the services when other variables remained constant. This result might be due to the information obtained from extension workers had the power to increase the awareness and know-how of farmers towards technologies and efficient utilization of the existing resources to decrease their inefficiency and wastage of resource use. That is, farmers who had more extension contact during the cropping period were economically more efficient than those who had less extension contact during the cropping period. Thus, the frequency of extension contacts with development agents is crucial to increasing the economic efficiency of maize production in the study areas. Farmers who had more contact with such agents improved their access to improved inputs and farming management practices, thereby increasing their production efficiencies. This result is consistent with the findings of Desale (2017), Daniel (2016), and Bealu (2013).

**Experience on farming** unexpectedly, the coefficient of farming experience of farmers on maize production negatively affected the economic efficiencies (EE) of farmers significantly at a 1 % level of probability. The marginal effect result, as the farming experience increased by one year, the probability of economic efficiency of farmers was decreased by 0.34 when other factors remained constant. Its negative sign might be due to those farmers having more experience in farming not being responsive to modern inputs combination that minimizes their costs. They may be experienced more on their traditional technology, which consumes more money and time. However, the sign of the coefficient for economic efficiency is negative, which is contradictory to our expectations. Farmers with many years of production experience have higher capital accumulation than those who have little experience. Therefore, once the farmer accumulates capital the desire for farming might be weak, and he will shift to other business activities instead.

**Distance to the market** of the household head showed a negative effect on the economic efficiency (TE) of the maize farms and was significant at a 5% level. The marginal effect result revealed that an increase in the distance to the market by one kilometer reduced the level of probability of economic efficiency by about 0.11 percent, and other variables remained constant. This implies that since the farmers are far from the market, their inefficiency increases because it incurs more costs to transport inputs and outputs, transaction costs, and market information. This result is consistent with the findings of Essa (2011), Hassen (2011) and Musa *et al*(2015).

Training of the household head showed a positive effect on the economic efficiency (EE) of the maize farms and was significant at a 1% level. From the marginal effect result, an increase in the number of farmers who attended training in maize production increases the probability of economic efficiency of farmers by about 4.32 percent than farmers who did not. This result suggests that farmers who attended training in maize production-related courses are supposed to be more efficient than those who did not, but the result of this study states otherwise. This result also indicated that farmers who attended training in the study area were more efficient than farmers who did not.

The seed variety of the household head showed a positive effect on the economic efficiency (EE) of the maize farms and was significant at a 1% level. From the marginal effect result, Farmers using improved seed Variety of the household head increase the probability of economic efficiency of a farmer by about 3.07 percent when other variables were kept constant. This result is consistent with the findings of Essa (2011), Nejuma (2012), and Bealu *et al*, (2013). The impact of improved maize varieties on economic efficiency is very high. Most improved varieties released by agricultural research institutes worldwide have proven to be high-yielding vis-a-vis traditional varieties.

## 4 Conclusion and Recommendations

This study was conducted to estimate Technical efficiency, Allocative efficiency, and Economic efficiency and to identify factors affecting economic efficiency among maize Producer households in Dega Damot *Woreda*, Amhara Regional State, Ethiopia.

The agricultural outputs could be increased either through the introduction of modern technologies or by improving the efficiency of inputs. This implies the need for the integration of modern technologies with improved levels of efficiency.

Several studies have dealt with the technical efficiency of farmers in developing countries. However, many of the researchers focused only on technical efficiency. So, technical and allocative efficiency are essential in improving the productivity gains from existing technology. Also, there was no study on the economic efficiency of smallholder maize producers in the study area. The estimates of the Tobit regression model also showed that among the total variables, nine (sex of household, education level, distance to market, access to credit, household size, extension service, group membership, training and seed Variety) were statistically significant in affecting the level of technical efficiency, whereas, nine variables (household head age, family income, gender, household size, experience, group membership, training, seed variety and extension service) significantly influence allocative efficiency of maize production. Moreover, the result of the model also revealed that ten (Age, gender, group membership, training, extension service, distance to market, experience, household size, family income, and seed variety) factors were important in influencing the economic efficiency of households in the study area. The study results also revealed that there is considerable variability in all efficiency scores of sample households in the production of maize in the study area. Therefore, less efficient farmers increase their efficiency level by adopting the practices of relatively efficient farmers in the area. So, based on the results, suggestions are made for increasing the productivity and efficiency of maize production. Therefore, based on the findings of this study, policy implications are made to enhance resource use efficiency and increase maize productivity in the study area.

A high level of financial support should help to acquire necessary inputs for maize production and expand extension services for easy adoption of technology and implementation of inputs used. Attainment level is an important factor in TE, AE, and EE, the key policy implication is that appropriate policy should be designed to provide adequate and effective basic educational opportunities for farmers in the study area. The government should invest in and encourage credit service provider satisfaction to solve problems associated with the utilization of credit.

Policies and strategies that improve extension services could help raise the efficiency of maize production. Hence, the number of visits by households to extension agents should be increased through subsequent training programs.

Further, given the complementarities of extension services, the expansion of basic and functional educational provisions in rural areas must be considered a key strategy for achieving increased Smallholder household agricultural productivity.

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### Conflict of Interest

The authors declare that they have no known competing financial interest or personal relationship that could have appeared to influence the work reported in this paper.

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