EJED 2023 5(2):37–55
Ethiopian Journal of Environment and Development
http://journal.du.edu.et/index.php/ejed

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

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Received: 04 August 2023 *Accepted: 27 December 2023* *Published: 30 December 2023*

DOI: **10.20372/ejed.v05i2.04**

Abstract

Ethiopian agriculture's low production can be attributed to a number of issues, including legislative limitations, drought, conflict, a lack of basic infrastructure, and demographic and economic factors. Many researchers are just concentrating on technical efficiency in an attempt to solve this issue. Allocative and technical efficiency are therefore crucial for enhancing the productivity gains from current technologies. To assess this cross-sectional research was carried out. Multistage sampling method was used and 366 households randomly selected. While determinants influencing efficiency level were identified using the Tobit model, technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE) levels were estimated using the stochastic frontier function. The result revealed that the mean TE, AE, and EE were 90.3%, 59.9%, and 76.4% respectively. As per Tobit model findings, TE was significantly impacted positively by gender, group membership, training, extension services, seed variety, and distance to market, whereas TE was significantly impacted negatively by household size and educational attainment. While household size had a substantial negative impact on AE, other factors including age, gender, group membership, training, extension services, and seed type showed favorable significant effects. The following factors also significantly improved EE: age, gender, group membership, training, extension service, and seed variety. Nonetheless, EE was significantly impacted negatively by household size, experience, and market proximity. The findings indicated that, by improving seed, there is a chance to boost the productivity of maize production in the research region. In order to improve the efficiency level of maize producer farmers, policies and research initiatives may influence these variables.

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

1 Introduction

Ethiopia's primary economic activity is agriculture. Two-thirds of people in developing nations reside in rural areas, according to the United Nations Development Program (UNDP, 2015). Most rural residents, many of whom are small-scale farmers, rely on agriculture as their primary source of income and subsistence. A hand-to-mouth lifestyle is the norm for farmers in underdeveloped nations that rely on farm income. This is a result of low livestock output, fast population expansion, and technological backwardness (FAO, 2014).

In Ethiopia, agriculture is the main industry, supporting the livelihoods of over 85% of the workforce, and this employment contributes roughly 45% of the country's GDP and 86% of its foreign exchange earnings (FDRE, 2016). As a result, the Ethiopian government has implemented measures aimed at promoting success, which can be guaranteed by increasing market performance and efficiency through lowering losses. Low productivity in Ethiopian agriculture is a result of both technical and socioeconomic issues. Due to ineffective management, a lack of use of contemporary agricultural technologies, outdated farming methods, inadequate supplementary services like extension, credit, marketing, and infrastructure, and biased agricultural policies, farmers with identical resources typically produce different amounts of output per hectare (WFP, 2012).

Cereals make up 65 percent of agricultural value added, or roughly 30 percent of the national GDP, and maize is the most important crop in terms of both crop output and the number of farmers involved in cultivation (Shahidur *et al*., 2010). The main producers and consumers of maize in Ethiopia are smallholder farmers, who make up almost 80% of the country's population (Dawit *et al*., 2008). As a key staple item for food security and the general growth of the agricultural industry, maize plays a crucial role in agricultural policy decisions.

Since agriculture is the main economic sector in Ethiopia, the government has worked hard to increase smallholder farmers' agricultural productivity and efficiency (Jema, 2008). Modern technology can be introduced to increase maize production, or current technologies can be improved to increase input efficiency. Since the introduction of new technology cannot bring about the anticipated shift of the production frontier if the current level of efficiency is low, these two are not mutually incompatible. This finding suggests that integrating contemporary technologies with higher levels of efficiency is necessary (Kinde, 2005).

According to this study, economic efficiency is the capacity of a farmer to use their existing resources as efficiently as possible in order to generate the greatest amount of output at the lowest practical cost. It includes both technological and allocative efficiency. Both technical and allocative efficiencies must be estimated in order to properly analyze farmers' economic efficiency. Thus, this study examined the economic efficiency of smallholder farmers' maize production; increased efficiency would support sustainable farming and better well-being for a sizable portion of Dega Damot Woreda, West Gojjam Zone, Amhara Region.

According to earlier studies conducted in Ethiopia, there is a significant disparity in grain yields across farmers, which may be caused by a variety of variables, including inadequate management, climate-related issues, and a lack of expertise and information about new crop technology (Sisay *et al*., 2015).

Many researchers only look at technical efficiency, ignoring the potential benefits for producers from the overall performance of how farmers allocate their resources in response to price incentives, which is a key factor in determining the farming enterprise's profitability. Thus, enhancing the productivity gains from current technology requires both technical and allocative efficiency. To the best of the researcher's knowledge, however, no research has been done on the economic efficiency of smallholder maize growers in the study region.

Therefore, by addressing technical, allocative, and economic efficiencies of smallholder farmers' maize production in the research area and offering empirical information on smallholder resource use efficiency, it is necessary to close the current knowledge gap. With the goals of assessing the degree of technical, allocative, and economic efficiencies of maize production and determining the factors influencing them in the study area, the current study is helpful in developing suitable policies and research data for lowering the degree of economic inefficiency.

Thus, this research addresses the following goals.

1. To assess the economic, technical, and distributive efficiency of smallholder farmers' maize production in the Dega Damot woreda, West Gojjam zone.

2. To determine the primary factors influencing maize production efficiencies in the research region.

2 Materials and Methods

2.1 Description of the Study Area

Dega Damot is a woreda in Ethiopia's Amhara Region's West Gojjam zone. Part of the Mirab Gojjam Zone, it is 399 kilometers from Addis Ababa, Ethiopia's capital. Dega Damot shares borders with Dembecha to the south, Jabi Tehnan to the southwest, Kuarit to the west, and the Misraq Gojjam Zone to the north and east. The population density of 183.27 people per square kilometer in Dega Damot is higher than the Zone average. In this Woreda, 33,336 households were counted, meaning that there were 32,497 dwelling units and an average of 4.57 people per household.

In Dega Damot, Amhara people make up the main ethnic group (99.95%). Of the population, 99.97% speak Amharic as their first language. With an average rainfall of between 900 and 1200 milliliters, the woreda is also known for its pleasant climate for the majority of the year (CSA, 2007). In Ethiopia's poorest and most food-insecure areas, such as Dega Damot woreda, maize is one of the main staple crops. The crop is grown in unfavorable circumstances, like marginal lands and low input utilization. The Dega Damot woreda's environment is ideal for growing a wide range of crops, including oil seeds (fruit and vegetable), teff, wheat, barley, beans, peas, sorghum, and maize.

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

2.2 Method of Data Collection

For this investigation, both primary and secondary data were employed. Questionnaires were manually distributed during the 2017–18 farming season in order to gather primary data. 366 respondents participated in the study in order to gather primary data using structural questionnaires. In-depth qualitative data was gathered through interviews. Four extension agents—one from each kebele—were interviewed in a structured manner. Focus Group Discussions (FGD) were used to gather people's opinions and worries regarding the production of maize. Interactions between participants and the researcher are made possible through focus groups. Four farmers from each kebele made up the group.

2.3 Sample Size Determination and Sampling Technique

To examine the economic efficiency of smallholder maize growers, a multi-stage sampling technique was used. Due to the huge number of families that produce maize and the volume of maize produced in the study area, Dega Damot Woreda was purposefully chosen for the study in the first stage. 32 kebeles make up the Dega Damot woreda in the second stage. Of them, 27 rural kebeles are important producers of maize. The primary target locations for the sample selection are maize producer kebeles, as the research primarily focuses on maize production. Due to the uniformity of maize production across all kebeles, four of the 27 kebeles are chosen at random in the third stage. Lastly, using the systematic random sampling (SRS) technique based on probability proportional to size (PPS), 366 sample farm households were chosen from the total households of four kebeles based on the list of households of the kebeles that produced maize during the 2017–18 production year.

2.3.1 Sampling Size Determination

The agriculture and rural development office of Dega Damot woredas reports that there are 4370 households spread over the four rural kebeles. The researchers used a formula developed by Yamane (1967) with a precision level of, ±5 (because the target population is homogenous).

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

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, $n = 366$

In accordance with the size sampling procedure, 366 farmers in total were chosen from the four kebeles based on this methodology. Four rural kebeles out of the 27 were chosen at random, and the respondents from these kebeles were used as a sample using the methods outlined 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

Descriptive statistics and econometric techniques were used to assess the data gathered from various sources. Some significant features of the sample households were compiled using the descriptive analysis. Tables, basic ratios, percentages, frequencies, standard deviations, and more are all part of the descriptive technique.

A two-limit Tobit regression model and a stochastic frontier model (SFM) were employed in the econometric analyses. Estimating the effects of inputs on maize output, measuring the economic efficiency of maize production using the stochastic frontier production model with maximum likelihood estimation, and identifying factors influencing the economic efficiency of smallholder maize producers using the two-limit Tobit model in Dega Damot Woreda were the goals of the econometric approach. To support the findings of the quantitative analysis, a summary and presentation of the qualitative data were also made. STATA software and the Frontier 4.1c program were used to examine the data.

Model Specification and Estimation Procedures

The original models for Aigner *et al.* (1977) and Meesuen and van den Broeck (1977) proposed a stochastic frontier production model, which Battese and Coelli (1995) applied to cross-sectional data in order to assess the impacts of input on maize output using maximum likelihood estimation. The stochastic production function was employed in this study because to its two main characteristics: a one-sided component and a two-sided, symmetric term that make up the disturbance term.

Cobb-Douglas stochastic frontier production function Model

One of the two functional forms for the production functions is either Translog (TL) or Cobb-Douglas (CD). The sole model stated in this study was the CD model, and log-likelihood ratio tests were used to determine which model was best.

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)

Estimated as the sum of output elasticities for all inputs, RTS is a measure of returns to scale that shows the percentage change in output as a result of a proportionate change in the utilization of 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 β_0, β_1, β_2, β_3, β_4, and β_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, α_i represents the parameters of the cost function to be estimated and ε_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

To honor Tobin (1958), who was the first to introduce censoring in economics, the Tobit Model is estimated using the censored regression model, often known as the Tobit model. The Tobit model, the most used censored regression model, uses an underlying latent variable to reflect the observed level. A Tobit is a type of censored regression model where the dependent variable is only tracked if it falls or rises above a predetermined threshold.

The dependent variable in the Tobit model, a censored normal regression model, is continuous, and its range is limited by a cut-off point from both above and below. Between zero and one, or inside a double-bounded range, is where the dependent variable is located. It makes sense to employ the Tobit model as using OLS results in skewed and inconsistent parameter estimates (Gujarati, 2004). Economic efficiency (technical and allocative efficiency) scores are the dependent variables in the model. These scores will be regressed against the common independent variables, which include the household head's age, education, gender, experience in maize production, extension services, group membership, distance to market, family income training, and seed varieties. It was anticipated that several explanatory factors will either directly or indirectly affect the economic efficiency (technical and allocative efficiencies).

Using a two-limit Tobit regression model, the factors influencing economic efficiency levels were measured. A set of socioeconomic, institutional, demographic, and other characteristics that were thought to be significant predictors of efficiency were used to regress the predicted efficiency scores. Given that the values of the dependent variables (efficiency scores) were within a specific range (0, 1), the Tobit regression model was thought to be more suitable.

A two-limit Tobit model was used to estimate three distinct equations for the determinants of technical, allocative, and economic efficiency, with the technical, allocative, and economic efficiency indices, respectively, serving as the dependent variable. The two-limit tobit model was defined as follows in accordance with Amemiya (1981), Waluse (2011), Essa *et al.* (2011), and Endrias *et al.* (2013):

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

Where *Yi** is the latent variable representing the efficiency scores, β_0, β_1, ..., β_{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, μ_i is an error term that is independently and normally distributed with mean zero and variance σ^2 ($\mu_i \sim$ IN 0, σ^2).

2.5 Diagnostic Tests

2.6.1. Test for Heteroskedasticity

When the conventional linear regression model's assumption of equal variance of residuals is broken, it is known as the heteroscedasticity test. In this case, the estimates of the variances are biased and the estimators are impartial but ineffective, which leads in invalid tests of significance (Maddala, 1992). Determining whether heteroscedasticity exists is the first step in solving the heteroscedasticity problem. Gujarati (2004) lists a number of tests for detecting heteroscedasticity, including the Breusch-Pagan, White's, PBPG, and Koeker Basset tests.

To confirm that the variance was constant, a heteroskedasticity test was conducted. For heteroscedasticity, the Breusch-Pagan/Cook-Weisberg test was applied. For both models, the robust option was used in the MLE regressions to account for heteroscedasticity (Baum, 2006).

2.6.2 Multicollinearity

Multicollinearity tests were also performed on the data. To check if the models have multicollinearity, the Variance Inflation Factor (VIF) was used. A scenario known as multicollinearity occurs when there is a significant degree of correlation between the independent variables.

A VIF value more than 10 is typically seen as a sign of significant multicollinearity and ought to be removed from the model, according to Gujarati (2004). The Variance Inflation Factor (VIF) was used to test for multicollinearity across all of the variables that were entered into the model, simultaneously for both continuous and dummy variables. Additionally, the contingency coefficient and variance inflation factors were used to verify the multicollinearity tests of dummy and continuous variables, respectively.

3 Result and Discussion

3.1 Estimating the Result of the Production and Cost Function

Table 2 shows maize farmers' maximum likelihood estimates (MLE) for the parameters of the stochastic frontier production function. The output values with the exception of labor, all input variables exhibit positive elasticity and significantly impact the growth of maize output. This implies that maize productivity falls as labor rises. According to this outcome, employing additional workers on a given amount of land may result in labor redundancy and a labor surplus, whose removal would essentially leave output unaltered.

Fertilizer: One important land-augmentation input that raises the productivity of existing land by raising yield per unit area is fertilizer, both chemical and organic. At the 1% level, the farmer's fertilizer coefficient is substantial and positively correlated with maize yield. Research suggests that a 1% increase in fertilizer quantity in kilograms will result in an 11.1% increase in maize production. The other input doesn't change. However, in order to prevent a declining return on fertilizer, this kind of relationship is predicted when the available fertilizer is used effectively in terms of rate in conjunction with other inputs. This outcome is in line with what Netabirabose (2017) found. Fertilizer was statistically significant at the 1% and 5% levels and had a favorable effect on production.

Land: The size of the farm, or land, is another important factor. Additionally, it was discovered that the coefficient of land was positive and significant at the 1% level. The largest output to land coefficient (24.4%) suggested that the primary factor influencing maize productivity in the research region is land. Land has a pretty big impact on maize output. In other words, if all other inputs stay the same, a 1% increase in farm size measured in hectares results in a 0.244% increase in maize production. The 1% statistical significance level for farm size suggests that changes in farm size had a significant impact on production efficiency.

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

Variable	Parameter	Coefficients	Std. Error	Z	*p*-value
Constant	β_0	5.45	0.187	29.19	0.000
ln(land)	β_1	.244	0.0858	2.84	0.005
ln(labor)	β_2	0.0163	0.0684	-0.24	0.811
ln(seed)	β_3	0.103	0.046	2.27	0.023
ln(oxen)	β_4	0.219	0.086	2.55	0.011
ln(fertilizer)	β_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
σv		0.153	0.016		
σu		0.130	0.051		
σ^2		0.040	0.009		
λ (lambda)		0.848	0.066		
γ (gamma)		0.522			

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

This indicates that there is room to grow the farm in order to increase output. This outcome is comparable to Tarekegn's (2017) findings, which showed a substantial relationship between cumin output and farm size.

Oxen: The primary source of draft power for tasks like plowing and agricultural planting in the majority of developing nations, including Ethiopia, is oxen. At the five-level, the predicted coefficient of oxen days—one oxen-day is equal to eight working hours—was identified as positive and significant. The positive indicator suggests that maize production can be increased by employing more ploughs. Therefore, if all other inputs remain the same, a 1 percent increase in the daily number of oxen will result in a 21.9% increase in the output of maize. This result aligns with the research conducted by Getachew (2017) and Bealu *et al.* (2013).

Seed: The results also indicated that seed had a positive impact on maize productivity, with significance at the 5% level. Therefore, with everything else being equal, a 1% increase in seed quantity in kilograms will result in a 10.3% increase in maize production. To boost their maize production, it could be preferable to use certified and improved maize seeds. Seed is the most important input for crop yield, according to research by Bealu *et al.* (2013) and Tarekegn (2017).

Given that the Wald $Chi-square$ statistic is significant at the 1% level (Wald $Chi-square$ statistic = 752.41 and probability = 0.000), we reject the null hypothesis that inefficiency does not exist in favor of the presence of inefficiency. The important test can be used to determine whether technical inefficiency effects are absent. In the half-normal model, the important log-likelihood value is λ=σu/σv. If λ is equal to zero, then all deviations from the frontier are caused by noise and there are no technical inefficiency effects (Aigner, Lovell, & Schmidt, 1977). Since the estimated value of λ = 0.848 differs considerably from 0, the null hypothesis—that there are no inefficiency effects—is rejected at the 1% significance level.

The variance parameter gamma (γ), which ranges from zero to one, is the ratio of the variance of technical efficiency particular to a farm to the overall variance of production, according to the results of Maximum Likelihood estimations of variance parameters.

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

Thus, it is possible to draw the conclusion that maize production is inefficient. Technical inefficiency accounted for almost 52% of the overall variation in maize farm output, according to the calculated γ value of 0.52. Therefore, the inefficiency component accounted for 52% of the variation in the composite error term. This finding also implies that random shocks beyond the farmer's control accounted for roughly 48% of the variation. For example, the temperature and weather during the cultivation of corn. The yield of maize can be optimized if technological inefficiencies among producers are reduced.

3.2 Efficiency Scores

Technical efficiency (TE) and cost efficiency (CE) were estimated using the Frontier version 4.1c computer program. The ratio of the actual cost to the ideal cost is known as cost efficiency.

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)

Consequently, technical, allocative, and economic efficiency will always be limited between 0 and 1, whereas cost efficiency will always fall between 1 and infinite. Calculate economic efficiency to take the inverse of cost efficiency, however, to keep the conversation focused on technical efficiency from the production function and cost efficiency from the cost function. The following is an estimate of the allocative efficiency derived from technological and economic efficiencies: AE is equal to EE/TE. After the estimation of the cost function and the stochastic frontier production function, respectively. The sample farm of Dega Damot Woreda has mean scores of 90.3%, 76.4%, and 59.9% for technical, economic, and allocative efficiency, respectively. The farms that were sampled had the following minimal technical, allocative, and economic efficiency scores: 0.755%, 0.309%, and 0.526%, respectively. The sampled farms had maximum allocative technical and economic efficiency scores of 90.9%, 82.6%, and 96.3%, respectively.

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

The parameters influencing economic efficiency levels were measured using a two-limit Tobit regression model. A set of socioeconomic, institutional demographic, and other characteristics that were thought to be significant predictors of efficiency were used to regress the predicted efficiency scores. The main goal of assessing TE, AE, and EE levels is to identify the variables that affect each farm household's efficiency level and to develop and implement policies that increase that efficiency. The Tobit regression model was used to regress the model's TE, AE, and EE scores on institutional, socioeconomic, and demographic factors that account for differences in inefficiency among farm households.

3.3.1. Determinants of Technical Efficiency

The results of a tobit regression of the socioeconomic, demographic, and institutional factors that affect technical efficiency scores in the research area are displayed in Table 4. The variables that were identified were: family income, seed variety, distance to market, extension service, gender, education level, experience, household size, group participation, training, and family income.

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

The findings of this study's Tobit model are examined for each important variable in the following manner.

At the 1% level, the gender of the head of the family was found to have a considerable beneficial impact on the technical efficiency (TE) of the maize fields. According to the marginal effect result, the sex of the household head from (0=F, 1=M) raises the likelihood that farmers will be technically efficient by roughly 1.2 percent. Another implication is that households headed by men are technically more efficient than those headed by women. Male family heads may have more practical farming expertise, which could be the explanation.

Furthermore, it might be argued that poor technical efficiency levels result from female family heads being overly preoccupied with home chores and lacking the time necessary to manage their maize plots. This outcome aligns with Muluken's (2014) findings.

A Group membership: A maize farmer who was a member of a producer cooperative or group also had an impact on technical efficiency. As a result, the technical efficiency (TE) of the maize fields was found to be positively impacted by the household head's group membership, which was significant at the 1% level. An rise in group membership in farmers' cooperatives also raises the likelihood of technical efficiency, according to the marginal impact result. Assuming all other factors remain unchanged, farmers who joined farmers' cooperatives increased their technical efficiency levels by 1.057 percent more than those who did not join farmer organizations. This outcome is in line with Bealu *et al*. (2013)'s findings.

Theoretical distance to market: It is postulated that technological efficiency was inversely correlated with the distance of maize production to the market. Technical efficiency was higher in households closer to the factor markets than in households farther away.

The surprise discovery, however, was that the technical efficiency (TE) of the maize fields was positively impacted by the household head's distance to the market, and this effect was significant at the 1% level.

According to the marginal effect result, if all other factors remain constant, a one-kilometer increase in the farmer's distance to the market results in a 0.045 percent rise in the farmer's chance of technical efficiency. Therefore, in order to achieve a higher degree of technological efficiency, farmers must have easy access to inputs and enhanced communication channels. This results contradicts the findings of Ntabakirabose (2017) and Bealu *et al*. (2013), who found a negative correlation and a significant impact on technical efficiency.

Access to credit: One crucial component of agricultural production systems is finance availability. It enables the manufacturer to meet the financial demands brought on by the production cycle. Because it temporarily addresses the need of operating capital and liquidity, the quantity of credit boosts farmers' productivity. The amount of credit was postulated in this study so that farmers who receive more credit from formal or informal sources during a given production season should be more productive than those who receive less credit. The technical efficiency (TE) of the maize farms was found to be positively impacted by the household head's access to finance, and this effect was significant at the 1% level. According to the results of the marginal effect, the likelihood of technical efficiency is increased by roughly 0.75% for a household head who has access to credit. This outcome aligns with the research conducted by Musa *et al*. (2014) and Netabirbose (2017).

Training: Developing the managerial skills of the head of the home requires training. It is predicted that household heads who acquire instruction in crop production and marketing, or any other associated agricultural training, are more productive than those who do not. It was crucial to train farmers on maize crops since it may enhance their knowledge of production methods and other topics. For a few days, a number of farmers in the study areas received instruction on maize, mostly on enhanced packaging and production techniques.

The results indicated that household head training had a significant positive impact on the technical efficiency (TE) of the maize fields at the 1% level. According to the marginal effect result, the likelihood of farmers becoming technically efficient is increased by around 0.79 percent for every farmer who attended training in maize production. According to this finding, farmers who received instruction were theoretically more productive than those who did not. This outcome aligns with the research conducted by Bealu *et al.* (2013) and Netabirbose (2017).

Seed variety: At the 1% level, the household head's seed variety had a considerable beneficial impact on the technical efficiency (TE) of the maize farms. According to the marginal effect result, farmers who used better household head seed varieties had a roughly 0.91% higher chance of being technically efficient; all other factors remained unchanged. In theory, farmers are more efficient than others if they have at least one plot of enhanced seed. A dummy variable called "seed variety" indicates whether or not the farmer used better seeding techniques.

It was predicted that farmers who used seed variety would be more productive than their counterparts since it reduces expenses and improves the quality of the seeds needed to produce maize. The results of Bealu *et al.* (2013) are in line with this outcome.

The technical efficiency (TE) of the maize farms in the study area was negatively impacted by the household head's educational attainment, and this effect was significant at the 1% level. According to the marginal effect result, farmers' chances of being technically efficient dropped by 0.45% as their years of education increased, while all other factors stayed the same. This outcome is in line with Getachew *et al*. (2017)'s findings. The findings of Alemu *et al.* (2009) indicate that efficiency is reduced by schooling.

It is argued that a farmer may have better prospects outside of farming as their level of schooling rises. In the end, this lowers efficiency by reducing the amount of labor available for maize production in the home. Additionally, Adesina and Djato (1996) have opinions about how education affects productivity. They argue that although uneducated farmers may have more farming experience and expertise than their educated counterparts and may be technically more effective, educated farmers may not always be more efficient than uneducated farmers.

Evidence from Battesse and Coelli (1995) refutes these claims, demonstrating that education improves farmers' efficiency and their capacity to use current technology. Unexpectedly, these research show a negative correlation between schooling and technological efficiency. This outcome contradicts the conclusions of Bealu *et al.* (2013), Mustefa *et al.* (2014), and Muluken (2014). This study demonstrated that education significantly and favorably affects all kinds of efficiency. It reaffirmed how crucial education is to raising manufacturing efficiency. It is a variable that is anticipated to improve managerial skills and result in wise farming judgments. Literate farmers are better equipped to manage their farm resources and agricultural activities than illiterate ones due to their superior abilities, information availability, and sound farm planning. They are also more likely to adopt enhanced production methods.

Household size (family size): The technical efficiency (TE) of the maize farms in the study area was negatively impacted by the household size (family size) of the household head, and this effect was significant at the 10% level. With all other factors held constant, the marginal effect result indicates that a one-person increase in household size would result in a 0.14 percent decrease in the likelihood of farmers being technically efficient. Due to a lack of funds, homes with a significant number of family members were unable to employ the proper input combinations.

Similar results were found by Musa *et al.* (2014), Essilfie *et al.* (2011), and Belete *et al.* (2014). Their reasoning was predicated on the idea that a big household size puts more strain on the farmer's limited resources because of rising household spending.

Extension service technical efficiency level was positively and considerably impacted by extension service at the 1% level. The marginal effect result showed that maize farmers who used extension services had a 0.75% greater level of technical efficiency than those who did not. There are no changes made to other variables. Efficiency rises as extension workers visit the farm household more frequently, according to the positive predicted coefficient for interaction with extension workers. The implementation of crop diversification has been comparatively more prevalent among farmers who have access to extension services than among those who do not.

Extension agents can help farmers carry out their crop diversification decisions since they possess technical expertise in crop production and enhanced production management techniques. As a result, suitable and sufficient extension services ought to be offered. The findings of Ahmed *et al.* (2013), Netabirbose (2017), Desale (2017), Daniel (2016), and Bealu *et al.* (2013) are all in agreement with this outcome.

3.4 Determinants of Allocative Efficiency

The results of a tobit regression of socioeconomic, demographic, and institutional factors on the effects of allocative efficiency scores in the research area are shown in Table 5.

The findings showed that allocative efficiency was significantly influenced by nine out of twelve variables. As was already mentioned, allocation efficiency plays a significant role in farms' overall productivity. One factor that might raise farms' overall production is the efficient use and distribution of resources.

The allocative efficiency (AE) of the maize farms was found to be positively impacted by the gender of the household head, and this effect was significant at the 1% level. When all other parameters were held constant, the marginal effect finding indicates that the sex of the household head from (0=F, 1=M) enhanced the chance of farmers' allocative efficiency by almost 3.57 percent. Additionally, it suggests that households led by men are more allocatively efficient than those headed by women. This might be the case because allocative efficiency necessitates a higher level of knowledge and expertise acquired with time, which boosts farmers' ability to allocate resources and technologies in the most efficient manner.

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 allocative efficiency (AE) of the maize farms was positively impacted by the age of the household head, and this effect was significant at the 5% level. When all other factors were held constant, the marginal effect result showed that the probability of allocative efficiency increased by 0.30% for every year that the household head's age increased. This suggests that older farmers are more productive than their younger counterparts. This might be the case because allocative efficiency necessitates the accumulation of knowledge and expertise over time, which enhances farmers' ability to allocate resources and technologies in the most efficient manner. This implied that elderly farmers were more productive than younger ones. The reason for this could be that as farmers age, their combined farming experience makes them more skilled. This is in line with Daniel's (2016) findings.

Allocative efficiency (AE) of the maize farms was positively impacted by the household head's family income, and this effect was significant at the 5% level. Based on the marginal effect result, when all other factors were held constant, the chance of allocative efficiency rose by roughly 0.00029 percent for every unit rise in a household's family income. Farmers become more efficient as these family incomes rise. The reason for this is that having family money allows farmers to timely buy inputs that they are unable to supply with their on-farm income, shifting the financial restriction outward.

Therefore, by allocating effectively at an efficient cost of production, it allows farmers to optimize their output. The outcome is consistent with the research conducted by Mustefa (2014), Abebayehu (2011), and Hasen (2011).

The research area's maize farms' allocative efficiency (AE) was negatively impacted by the household head's family size, and this effect was significant at the 5% level. The marginal effect result indicates that, when all other factors are held constant, a one-person increase in household size would result in a 0.61 percent decrease in the likelihood of farmers being allocatively efficient. The reason for this could be that farmers with large families were less able to allocate resources optimally. The findings of Daniel (2016) and Hika (2016) are in line with this outcome.

The allocative efficiency (AE) of the maize farms in the study area was positively impacted by the household head's group membership, and this effect was significant at the 1% level. Assuming all other factors remain unchanged, the marginal effect analysis showed that farmers who belonged to farmers' cooperatives had higher levels of allocative efficiency than those who did not join farmer organizations by 5.16 percent. In theory, being a member of social groups aids producers in becoming more efficient. This outcome is in line with what Waluse (2012) and Bealu (2013) found.

At the 5% level, it was also discovered that extension services had a favorable and significant impact on allocative efficiency (AE) level. According to the results of the marginal impact, maize farmers who used extension services reported a 3.11% greater degree of probability of allocative efficiency than those who did not. Additionally, one significant factor influencing the allocative efficiency of farmers in the research area was the frequency of extension interaction. Farmers gained new knowledge and abilities from development agents, which led to this outcome. The findings of Mustefa (2014), Tarekegn (2017), Desale (2017), Daniel (2016), and Bealu (2013) are all in agreement with this outcome. The likelihood of maize market involvement increases by 0.47% when extension contact is increased by one day, according to the marginal effect result.

Experience: One of the socioeconomic elements that has received more attention in many stochastic production function studies is the impact of farming experience, which is typically expressed as the number of years the farmer has been engaged in maize farming. At the 5% level of significance, experience had a substantial impact on the sampled households' AE. According to the marginal effect result, when all other parameters were held constant, farmers' chances of being allocatively efficient dropped by 0.34 for every year of farming experience. Allocative efficiency's coefficient, on the other hand, has a negative sign, which goes against expectations. Its drawback could be that farmers with more farming expertise might not be receptive to cutting-edge input combinations that reduce expenses.

More capital has been accumulated by farmers with many years of productive experience than by those with less. As a result, the farmer may lose interest in farming after he has accumulated wealth and turn to other commercial endeavors. Therefore, this could result in smallholder farmers producing maize less efficiently. This outcome is consistent with previous research findings by Gosa (2014), Hika (2016), Getachew (2017), and Musemwa *et al* (2013).

At the 1% level, training the head of the household had a considerable favorable impact on the maize fields' allocative efficiency (AE). The probability of allocative efficiency among farmers is increased by approximately 5.53 percent compared to those who did not attend training in maize production, according to the marginal effect finding. They were able to use inputs in a cost-minimizing input ratio as a result of training. This outcome supports Nejuma's (2012) findings. Allocative efficiency (AE) of the maize farms was positively impacted by the household head's seed variety, and this effect was significant at the 1% level. Using the household head's enhanced seed variety increases the likelihood of the farmers' allocative efficiency by approximately 4.63% when all other factors stay the same, according to the marginal impact result. This outcome aligns with the research conducted by Bealu *et al*. (2013). Additionally, efficiency will rise with the usage of better seeds.

3.5 Determinants of Economic Efficiency

The findings showed that 10 out of twelve variables significantly contributed to economic efficiency.

At the 1% level, the family head's gender had a considerable favorable impact on the maize farms' economic efficiency (EE). According to the marginal effect result, the sex of the household head from (0=F, 1=M) raises the likelihood that farmers will be economically efficient by roughly 4.36 percent. Farm households led by men were more inclined than those headed by women to make decisions based on the market. Due to resource limitations for crop production, households led by women had this outcome.

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			

At the 1% level of significance, the age of the family head had a beneficial impact on the maize farms' economic efficiency (EE). When all other factors are held constant, the marginal effect finding shows that a one-year increase in the farmer's age raises the level of likelihood of economic efficiency by 0.22%. Older farmers are therefore more economically efficient. The elderly head of the home is more productive and efficient, according to the data. Because of this outcome, older households are more experienced and can effectively employ their prior knowledge to produce more with a given amount of inputs. This outcome aligns with the research conducted by Tarekegn (2017) and Nejuma (2012).

The economic efficiency (EE) of the maize farms was positively impacted by the household head's family income, and this effect was significant at the 5% level. According to the marginal effect result, when all other factors were held constant, a household's chance of economic efficiency rose by roughly 0.0002 percent for every unit rise in family income. The outcome agreed with Solomon (2014).

At the 5% level, the household head's family size had a substantial negative impact on the economic efficiency (EE) of the maize farms in the research area. When all other factors are held constant, one person reduces the likelihood of economic efficiency by approximately 0.43 percent and increases the size of the home headed by the householder, according to the marginal effect result. Household size is a surprising indicator of economic efficiency; one explanation for this could be that a bigger household size ensures family labor is available to complete farm tasks on schedule.

Because there is a labor shortage during peak seasons, households with larger family sizes are more efficient in producing maize because they assign more workers to complete essential farming tasks like plowing, weeding, and harvesting on time.

The economic efficiency (EE) of the maize farms in the study area was positively impacted by the household head's group membership, and this effect was significant at the 1% level. According to the marginal effect result, farmers who joined cooperatives had a roughly 3.84 percent higher chance of being economically efficient than farmers who did not join, when all other factors were held constant.

The participation of farmers in farmer cooperatives serves as a stand-in for gauging the contribution of social organization to productivity. Compared to non-members, farmers who are part of farmer cooperatives are given access to more useful knowledge about production technologies. They experiment with and implement new production technology as a result, making them more productive in the production of maize. This outcome aligns with the research conducted by Waluse (2012) and Bealu (2013).

Economic efficiency (EE) level was also found to be positively and considerably impacted by extension service at the 1% level. The results of the marginal effect showed that, when all other factors were held constant, maize farmers who used extension services had a 2.85% better chance of economic efficiency than those who did not do so. This outcome may have resulted from the knowledge that extension agents provided, which had the ability to lessen farmers' inefficiency and resource waste by raising farmers' understanding of technology and the effective use of already-existing resources.

At the 1% level, it was also discovered that extension services had a favorable and considerable impact on economic efficiency (EE) levels. The results of the marginal effect showed that, when all other factors were held constant, maize farmers who used extension services had a 2.85% better chance of economic efficiency than those who did not. This outcome may be the consequence of information gathered from extension agents, who had the ability to raise farmers' awareness of technology and the effective use of their current resources in order to reduce their inefficiency and resource waste.

Agricultural experience: Surprisingly, at a 1% level of probability, the correlation between farmers' farming experience and maize production had a negative impact on farmers' economic efficiency (EE). When all other parameters were held constant, the marginal effect finding showed that farmers' chances of being economically efficient dropped by 0.34 for every year of increasing farming experience. Its negative sign could be the result of more seasoned farmers not being receptive to the mix of contemporary inputs that reduces their expenses. They might have greater experience with their more expensive and time-consuming traditional technology. Our expectations are not met, though, as the coefficient for economic efficiency has a negative sign.

More capital has been accumulated by farmers with many years of productive experience than by those with less. As a result, the farmer may become less motivated to farm after he has accumulated wealth and turn to other commercial endeavors.

The economic efficiency (TE) of the maize fields was negatively impacted by the household head's distance to the market, and this effect was significant at the 5% level. When all other factors were held constant, the marginal effect finding showed that a one-kilometer increase in the distance to the market decreased the level of probability of economic efficiency by roughly 0.11 percent. This suggests that farmers who live distant from the market are more inefficient since it costs more to transport inputs and outputs, conduct transactions, and obtain market information. This outcome aligns with the research conducted by Essa (2011), Hassen (2011), and Musa *et al*. (2015).

The economic efficiency (EE) of the maize farms was positively impacted by family head training, and this effect was significant at the 1% level. According to the marginal effect result, farmers who participated in more training in maize production are more likely to be economically efficient than those who did not, by roughly 4.32%. The findings of this study contradict the notion that farmers who participated in training related to maize production should be more productive than those who did not. Additionally, this research showed that farmers who participated in training in the study area were more productive than those who did not.

The household head's seed variety had a significant, 1%-level beneficial impact on the maize fields' economic efficiency (EE). Based on the marginal effect result, farmers who utilize the household head's enhanced seed variety have a 3.07 percent higher chance of being economically efficient when all other factors are held constant. The findings of Bealu *et al*. (2013), Nejuma (2012), and Essa (2011) are all in agreement with this outcome. Improved maize cultivars have a significant effect on economic effectiveness. In comparison to traditional types, the majority of enhanced cultivars issued by agricultural research organizations around the world have demonstrated exceptionally high yields.

4 Conclusion and Recommendations

The purpose of this study was to determine the factors influencing economic efficiency among households that produce maize in the Dega Damot woreda of the Amhara National Regional State of Ethiopia, as well as to estimate technical, allocation, and economic efficiency. Improved input efficiency or the use of contemporary technologies could both boost agricultural productivity. This suggests that current technologies must be integrated with increased efficiency.

The technical efficiency of farmers in emerging nations has been the subject of numerous studies. But a large number of the studies solely looked at technical efficiency. Consequently, increasing the productivity advantages from current technology requires both technical and allocative efficiency. Furthermore, the research area's smallholder maize growers' economic efficiency was not examined.

The Tobit regression model's estimates also revealed that, of the total variables, nine (household head age, family income, gender, household size, experience, group membership, training, seed variety, and extension service) significantly influence the allocative efficiency of maize production, while nine (household sex, 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.

Additionally, the model's outcome showed that 10 factors—geography, age, gender, group participation, training, extension services, market distance, experience, household size, family income, and seed variety—were significant in affecting the economic efficiency of families in the research area. The study's findings also showed a significant degree of variation in the sample homes' overall efficiency scores for maize production in the study area. Thus, by following the methods of the more productive farmers in the region, less productive farmers raise their level of efficiency. In light of the findings, recommendations are given to boost maize production's efficiency and productivity. In order to improve resource use efficiency and raise maize yield in the study area, policy implications are therefore made based on the study's findings.

The acquisition of inputs required for maize production and the expansion of extension services for simple technology adoption and input implementation should be made possible by a high degree of financial support. The main policy consequence is that suitable policies should be created to offer sufficient and efficient basic educational opportunities for farmers in the research area, as attainment level is a significant influence in TE, AE, and EE. To address issues related to credit consumption, the government ought to make investments in and promote the satisfaction of credit service providers.

The efficiency of maize production could be increased with the support of policies and initiatives that enhance extension services. Therefore, through further training programs, the number of visits from families to extension agents should be increased.

Additionally, considering the complementary nature of extension services, expanding basic and functional educational options in rural regions need to be a top priority in order to boost the agricultural production of smallholder households.

Acknowledgments

We would like to the farmers who generously devoted their time and shared the required information during the data collection period. As well, we are thankful to Dilla University with the support of this study and for sending me for further education and released of learning fund.

Conflict of Interest

The authors affirm that none of the work described in this publication may have been influenced by any known competing financial interest or personal relationship.

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