Original Research Article

Maize Production Efficiency in Southern Ethiopia: The Stochastic Frontier Analysis

ABSTRACT

The study aimed to determine smallholder maize producers' economic efficiency and link farmers' observed efficiency levels with socioeconomic and institutional characteristics in Southern Ethiopia. A two-stage probability random sampling technique was used to select 384 sample farmers. The descriptive statistics, stochastic production frontier, and two-limit Tobit econometric model were used to estimate the efficiencies levels and identify the sources of maize production inefficiencies. The mean technical efficiency (TE), allocative (AE), and economic efficiency (EE) 's were 82, 75, and 62 per cent, respectively. Maize output was determined by land size, the quantity of fertilizer, family labour, oxen power, seed, and pesticides. Sources of maize production inefficiencies are the gender of the household, landholding, training, education, farm experience, membership in cooperatives, age, distance from the plot of land, off-farm activities, livestock holding, and distance from the credit institution. Mainly it provides more concrete recommendations to policymakers to focus on agricultural advisory and support services. Including the provision of credit and short-term training on advanced maize production technologies) for women and other disadvantaged groups, promoting the establishment of women farmer learning circles.

Keywords: Efficiency, Maize, Smallholder Farm, Stochastic Production Frontier; Tobit

INTRODUCTION

Global maize production was estimated at 1.05 million tonnes in 2020 (FAO, 2021). It is Africa's second most important food crop, after cassava, and it is grown in many environments. Per capita consumption of maize in Africa is the highest, particularly in eastern and Southern Africa. Maize is processed to offer various product ranges, which include whole maize meal flour, sifted maize meal, vegetable oil, flour for confectionery, dough, cornflakes, snacks, crackers, and starch converted to process sugars like glucose syrup and dextrose (Kpotor, 2012). Ethiopia is one of the world's centres of genetic diversity in crop germplasm, producing more maize than any other crop (CSA, 2014). Maize is Ethiopia's staple crop and is widely grown for the most part by smallholder farmers throughout the country. It has also continued to be an essential cereal crop in the SNNP regional state as a source of food and cash income (Million and Getahun, 2001). The national average maize yield in 2020 was 8,600 thousand tones (CSA, 2020)

Moreover, maize is a significant crop in Wolaita Zone in southern Ethiopia (WZAO, 2021). According to Kassa (2017), Farmers in Ethiopia grow maize mainly to consume its green cob as an additional meal. They also use it to make traditional food items like corn flour, porridge, bread, cornmeal for brewing beverages, alcohol, livestock feed, corn oil, and ethanol production. In the significant maize-producing areas of the Wolaita Zone, maize grain is utilized to consume multiple kinds of traditional dishes with or without mixing with other crops. However, due to its scarcity, the utilization of green maize stalks was limited to feeding cattle, particularly draught animals, dairy cows, and physically weak animals. Despite efforts to improve maize production over the years, low productivity remains a significant challenge in the agricultural subsector in Wolaita Zone. The average farm-level yields in the study area were 20qt/ha compared unfavourably with on-farm field trial yields of 50-60 qt /ha and with research field yields of 80-110 qt/ha (Dawit et al., 2010 as cited in Kassa (2017)). This means technological advances generated through research fail to be translated into increased efficiency and resource productivity (Geta, Bogale, et al., 2013 as cited in Kassa (2017). According to Mian et al. (2021), the optimum plant population of maize would be 9.74 plants/m2 (974000 plants/ha), and the predicted grain yield would be 10.13 t/ha. In the Guji zone of Ethiopia, the mean maize productivity is 19.2 quintal/ha, below the national level (Belete, 2020).

Despite the excellent maize production potential of this zone, the current maize productivity of the study area is below the optimum level. Therefore, it is required to expand output and productivity by increasing efficiency to sustain the efficiency of those operating at or closer to the frontier. This can be attained by identifying the production constraints through scientific research. Furthermore, improvements in efficiency and productivity lead to more maize output and food supply, reducing malnutrition and poverty. Therefore, this study estimated the TE, AE, and EE levels and identified sources of the inefficiency of maize production in *Damot Sore* district in southern Ethiopia.

METHODOLOGY

Area Description

This study was carried out in *Damot Woyede* district, 22 km from *Wolaita* zone town, Soddo, 145 km from the regional city of *Hawassa* in southern Ethiopia.

Data Type and Sampling

It used both secondary and primary data. The secondary data were collected from published and unpublished sources such as articles, journals, booklets, the internet, and national, regional, Zonal, and *Woreda* sector office reports. The primary data was collected through a household survey from sample households using an interview schedule. Moreover, data from key informant interviews and focus group discussions with farmers, local administrators, and development agents were used. In the survey, information was gathered on issues related to the socioeconomic factors that affect economic efficiency in maize production, farmers' knowledge about the production of maize inputs, and output.

Two-stage sampling techniques were used to select sample farmers in *Damot Woyede* District. In the first stage, from 20 kebeles, eight study *kebeles were* randomly selected based on the production potential of maize (WZAO, 2021). In the second stage, three *kebeles* were chosen from major maize producers based on the discussion with extension officers. Consequently, Anka *shashra, Galcha* sake, *Demba Girara* Kebeles were randomly selected. The Cochran (1977) sample determination formula was used to determine 384 sample households. Finally, 149, 140, and 95 families in a total of 384 homes were randomly selected from mentioned kebeles. This size was distributed in each sample kebele based on the probability proportional to household size.

Methods of Data Analysis

The research used descriptive statistics and econometric models to analyze the data. First, descriptive statistics such as mean, standard deviation, frequency, and percentage were employed to analyze the data collected on the sample farmers' socioeconomic, institutional, and agroecological characteristics. The two-stage stochastic frontier econometric production model composing errors and incorporating the effects of inefficiency proposed by Battese and Coelli (1995) was used. In the first stage, technical, allocative, and economic) was estimated, followed by the Tobit regression model to find inefficiency effects (technical, allocative, and financial inefficiencies) defined as an explicit function of certain factors specific to the farm and all parameters.

The technical efficiency of maize production is estimated in the following form of the SPF function of the CD type:

$$\ln maizeoutput = \beta_0 + \beta_1 \ln land + \beta_3 \ln lobor + \beta_4 \ln DAP + \beta_5 \ln \ fert + \beta_6 \ln ox + \beta_7 \ln seed + (V_i - U_i) \quad (2)$$

$i = 1, 2, 3...158$

$$\varepsilon_i = V_i - U_i \quad (3)$$

Where; $Inmaizeoutput$- maize output level of the i^{th} sample farmers measured in Qt,ln - Logarithm to base e, $V_i - U_i$= error term (ε), β_0 Constant term to be estimated, $Inland$; Land area used for the production of maize by the i^{th} sample farmers estimated in ha., $Inlabor$; is the amount of labour used by the i^{th} household measured in person-days, $InDAP$; is the quantity of inorganic urea fertilizer (NPS/DAP) used by the i^{th} household measured in kg/ha; $Inurea$; is the quantity of inorganic urea fertilizer (urea) used by the i^{th} household measured in kg/ha; $Inox$; is the amount of oxen power used by the i^{th} household measured in Oxen Days, $Inseed$; is the quantity of seed used by the i^{th} household measured in Qt/ha, $\beta_1 - \beta_5$: Coefficients of the input variables to be estimated; e_i: Composed error term, V_i denotes the random error with zero mean, N (0, δ^2v) which is associated with random factors such as measurement error in production and weather controlled by farmers and thought to be autonomously independently and identically distributed. As N (0, δ^2v) with a random error that is independent of U_i., U_i *denotes* the non-negative efficiency estimated in relative to the stochastic frontier that is i^{th} farmers are not attaining the maximum production (Technical inefficiency) and range between zero and one.

According to Bravo-Ureta and Pinheiro (1997), economic efficiency is the product of technical and allocative efficiency. The economic efficiency of each farmer is calculated as the product of allocative and technical efficiency. The model specification for economic efficiency is as shown in the equation.

$$EE = AE \times TE$$

Where i = 1, 2,...nth farmer
EE = Economic efficiency
AE = Allocative efficiency
TE = Technical efficiency

A stochastic production function was used to measure the factors affecting economic efficiency levels. The farm-specific economic efficiency is the division of minimum total production cost (C*) by the actual total production cost (C);

$$EE_i = \frac{C_i{}^*}{C_i} = \frac{P_i}{P_i X_i} X_i{}^* = \frac{E_i(C_{ii} | U_i}{E(C_I | U_i, \mathrm{Y}_i, p_i}, = 0, Y_i P_i) = e\left[(\frac{U_i}{\varepsilon_i}) \right] \qquad (4)$$

Cost efficiency (CE) and economic efficiency (EE) are then obtained from the inverse of cost-efficiency as follows (Hussain *et al.*, 2014)

EE = 1 /CE

The two-limit [0,1)]Tobit models were used to find the source of inefficiencies as defined below:

$$EE,\ TE,\ AE = \delta 0 + \textstyle\sum_1^{12} \delta 1 Zij + \mu i \qquad (6)$$

Where the efficiency scores, δ0, δ1, . . , δ12 are the parameters to be estimated, and EE, TE, and AE are the economic, technical, and allocative inefficiency of the ith farmer, respectively. Zi is demographic, socioeconomic, and institutional factors that affect the efficiency level., µi represents an error term that is independently with δ^2 ($\mu i \sim IN, 0, \delta^2$). Moreover, the farm-specific efficiency scores for the smallholder maize producers' range between zero and one. Therefore, the two-limit ([0,1]) Tobit model can be presented as follow.

$$Yi = \begin{cases} 1, if\ Yi \geq 1 \\ y\ \ if\ 0 < Yi* < 1, \\ 0, if\ Yi \leq 0 \end{cases} \tag{7}$$

The two-limit Tobit model allows for censoring in both tails of the distribution (Greene, 2003). The coefficients of variables represented by the above equations were estimated by the STATA version 14.

Input and Output variables

The response variable of the production function is the amount of maize output produced. It is the sample smallholder farmers during the 2018/19 production year measured in kg. Land used for maize production during the 2018/19 production season by every smallholder farmer measured in ha. It belongs to smallholder farmers who utilize hiring, leasing, or sharecropping arrangements. Seed refers to the amount of maize seed and a measured number of maize seeds in kilograms (kg) used by each smallholder farmer in the 2018/19 cropping season. It is the usage of both improved varieties of maize seeds and home-produced or local maize seeds. Labor input captures family, shared, and hired labour used for different agronomic practices of maize production in the 2018/19 production season. However, differences in sex and age among labourers would be expected. Hence, to add a homogeneous group of labour, the individual delivery was changed into Man Day Equivalent (MDE) using the standard developed by (Storck*et et al.*, 1991). Therefore, the human labour input was expressed in terms of total MDE. Urea and DAP fertilizers are the key inputs, and their application and other technologies could significantly increase crop productivity. Urea is applied to the farmland once or using the split application, but DAPS or NPS are usually applied during planting time only. Therefore, as input variables, the total amount of urea and DAP or NPS used in kg for the 2018/19-year maize production was considered in this study. Oxen draught power is used for different farming activities for maize. Production is measured in oxen days. Hence, oxen power was measured using the total number of oxen days allocated for various activities of maize production in the

2018/19 production season. Herbicide as input variable is the total amount of herbicide used in a litter (Lt) for the 2018/19-year maize production that was considered in this study.

Inefficiency determinant variables

The following variables are expected to determine the economic, technical, and allocative inefficiency of maize production in the study area. Thus, based on theoretical background and empirical evidence, smallholder farmers' socioeconomic, institutional, and agroecological characteristics are hypothesized to explain the efficiency differences observed among smallholder maize farmers.

Table 1: The hypothesized effects of independent variables on technical, allocative, and economic inefficiencies.

Variables	Description of variable	Measurement	Hypothesized effect on maize production inefficiency			Prior Researches
			TE	AE	EE	
Sex	Sex of household	One if male, zero if female	+		+	
Age	Age of the household	Years	+	+	+	Kitila and Alemu (2014) and Asefa (2011)
Training	Participation in agricultural training	Yes =1, No =0	+		+	
Experience	Farmers farm expriance	Years	++	-	+	
Membcoop	Membership in cooperatives	Yes =1, No =0	+	+	+	
Credit	Distance from credit service	Km	-	-/+	-	
Disexten	Distance to extension centre	Km	-/+		-	
Education	Formal education level farmers	Years	+	+	+	Kitila and Alemu (2014) and Asefa (2011);
Farm size	Farm size	Ha	+	+	+	Asefa (2011)
Livestock	Livestock size of household	TLU	+	+	+	Hassen (2011) ; Asefa (2011); Geta *et al.* (2013).
Off-farm	Income from off-farm activities	ETB[1]	+	-	+	Wassie (2012);Alemayehu (2010), Teklemariam (2014);; Hassen (2011); Asefa (2011)

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[1] Ethiopian currency currently one USD equals 42ETB

RESULTS AND DISCUSSION

Level of Productivity and Input utilization of Maize Production

The sampled smallholder farmers realized a mean yield of 39.199 qt/ha (Table2). Furthermore, the chemical fertilizers in the production of maize were DAP/NPS and urea. On an average mean of 2.11ha, the amounts of DAP/NPS and Urea applied by sampled farmers were 212.109 kg and 212.109.58 kg per ha, respectively. On the other hand, the average charges of seed-applied were 53.53kg per ha. Therefore, the mean amount of chemicals applied per ha was 2.1 litres. The survey results also revealed that, on average, the family time spent on labour days used in the cultivation of maize, first flowing, second flowing, and third flowing were 7.10,5.33, and 3.66 person-days per hectare, respectively (Table 2). As a result, the mean maize output per hectare is 39.19kg.

Table 2: Level of productivity and input application in maize production

Inputs	Mean	Std. Deviation
Amount of DAP/NPS in ha	212.1	80.5
Amount of urea in ha	212.1	80.56
Maize plot of land	2.1	0.803
The number of herbicides ha	2.1	0.803
Amount of seed in ha	53.4	30.25
Family member /labor1stflowing	2.71	1.143
Time spent first flowing	7.10	1.712
Time spent second flowing	5.33	1.273
Time spent third flowing	3.66	0.782
Maize product from plot land	39.199	19.3

Source: Computed from Field Survey Data, 2015/16

Cost of Inputs for Maize Production

The survey results revealed that on average small farms incurred 3224 ETB for DAP or NPS and Urea 30707 ETB. The mean cost of the smallholder farms incurred for improved seed was 1875ETB. The sample farm means the price of land rented was 1075 ETB, and the mean cost of herbicides per ha is 772.39 ETB. The mean total cost of maize production of sample farms is 10270 ETB. The sample farm means the cost of oxen power was 203.1 ETB.

Table 3: The amount of cost in production

Cost input per ha	Mean	Std. Deviation
The total cost of DAP/NPS	3224	1239.5
The total cost of urea	3070.7	1169.16
The total cost of labour	58.90	211.717
The total cost of land rented	1075.	1997.93
The total cost of seed	1875	689.5
Total cost herbicides	772.39	284.04
The total cost of oxen power	203.1	74.4

Parameter Estimates of the Stochastic Production and Cost Functions

The Cobb-Douglas functional form of the stochastic frontier model with a half-normal distributional assumption of the error terms is considered to estimate the model's parameters. The parameters were estimated simultaneously with those involved in the model for the inefficiency effects. Table 4 presents the results of ML estimates of the inefficiency model.

As indicated in Table 4, the results of the Cobb-Douglas Stochastic Production Frontier showed that land and family labour were found to be at 1%. At the same time, the remaining four variables, seed, fertilizer, and oxen power, were significant at a 5% level, and herbicides insignificant. Besides what one would expect, the herbicide was not statistically different from zero. One of the appealing features of the Cobb-Douglas functional form is the direct interpretation of its parametric coefficients as a partial elasticity of production concerning the input. This attribute allows one to evaluate the potential effects of changes in the amount of each piece of information on the output. As shown in Table 4, the parametric coefficients or partial elasticity of significant input variables were 0.6 for land, 0.02121for dap, 0.08 for urea, 0.0723 for herbicide, -0.0345 for seed, 0.307 for family labour, and -0.07 for oxen power. These values indicated the relative importance of each factor in maize production. Land allotted for maize production appeared as the single most crucial factor, followed by family labour, urea, herbicide, and DAP improved allocated to maize and in order, respectively. This implies that at ceteris paribus, a unit per cent increase in it will increase the output of maize grain by 0.621%.

Summing up, the partial elasticity of production concerning every significant input for a homogeneous function is 1.206; this represents the increasing return to the scale. If the same proportion varies all factors, the coefficients indicate the percentage change in input provides more than a percentage change in maize output. These results were in complete agreement with those of, Wassie (2012), Mohammed (2012), and Oyewo (2011).

Table 4: the parameter estimates of the SPF model.

LANOUT	Coef.	Std. Err.	p-value
Land	0.621*	0.056	0.000
Dap	0.021*	0.009	0.026
Urea	0.08 *	0.06	0.0187
Seed	0.034*	0.012	0.006
Pesticides	0.07*	0.06	0.264
Family labour	0.31*	0.06	0.000
Oxen power	0.07*	0.063	0.02
Cons	6.9	0.35	0.000

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

Source: Computed from Field Survey Data, 2018/19

Furthermore, as indicated in Table 5, the results of the Cobb-Douglas Stochastic cost Production Frontier showed that the estimated cost coefficients are for the cost of land, cost of fertilizer, cost of family labour, and cost of chemical/herbicide/. The results showed that land cost and family labour cost were found to be significant at 10%, while the remaining three variables, cost of seed, cost of fertilizer (Urea), and cost of oxen power, were effective at a 1% level and worth of fertilizer (DAP) insignificant. Besides what one would expect, the herbicide was not statistically different from zero. One of the appealing features of the Cobb-Douglas functional form is the direct interpretation of its parametric coefficients as a partial elasticity of production concerning the cost used. As shown in Table 5, the parametric coefficients or partial elasticity of significant input variables were 0.25 for cost for land, 0.14 cost for dap, 0.39 cost for urea,0.047cost for herbicide, 0.229 costs for seed, 0.09 cost for family labour, and 0.173 costs for oxen power. Therefore, the 1% increase in the use cost of land, cost of DAP, cost of urea, cost of herbicide, cost of family labour, and cost of seed will result in 0.25%, 0.14%, 0.39%, 0.047%, and 0.307%,0.09, and 0.229 % increase in the efficiency level of maize output, respectively. Consequently, the cost of urea appeared as the single most crucial factor of production, followed by the cost of land, cost of oxen power, cost of dap, cost of family, and cost of chemicals, respectively. This implies that at ceteris paribus, a 1% increase in the price of urea will increase the output of maize grain by 0.39%.

The gamma value (γ=δ u2 / (δ v2 + 1); γ = 0.86 at Table 5 implies 86% variability is contributed by differences in decision maker's is due to inefficiency.

Table 5: The parameter estimates of the stochastic frontier cost function.

Output	Coef.	Std. Err.	tP>|t|
Land cost	0.25**	0.147	0.090
DAP cost	0.14***	0.17	0.32
Urea cost	0.39*	0.06	0.000
Seed cost	0.22*	0.08	0.001
Herbicide cost	0.047*	0.089	0.594
Family labour cost	0.09*	.058	0.096
Oxen power cost	0.173*	0.03	0.000
Cons	2.40	0.47	0.000
sigma *v* 0.1643011 Sigma *u* 0.4108257 sigma2 .1957726 γ = 0.86			

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

Source: Computed from Field Survey Data, 2018/19

Levels of Technical, Allocative, and Economic Efficiency

Table 6 presents the summary of all estimated efficiency levels of TE, AE, and EE. The maximum technical efficiency was 96%, and the minimum technical efficiency was 19%. AE for sampled farms was a minimum of 11.6%. Small hold farms operate with an economic efficiency maximum of 89.7% and a minimum of 12.5%

Moreover, table 6 presents the estimated efficiency level of TE, AE, and EE. The mean of TE for sampled farms is 0.82. This implies that the average maize producer only attains 82.7% of potential output under the prevailing technology. AE is at an output level where the price equals the marginal cost of production. The average AE is 0.746. It suggests that the maize farmers produced up to the average of 74.6% allocative efficiency point, and there is some space to optimize the structure of the input of maize production. Finally, with a mean of 0.620, economic efficiency holds. There is a need to improve technical and allocative efficiency in maize production in *Damote Woyede* District. Notably, the result suggests that a potential 38% improvement in economic efficiency would be achieved by optimizing the structure of the input and improving the technical production efficiency

Table 6: Summary of TE, AE, and EE estimation

Efficiency	Minimum	Maximum	Mean
TE	0.1961	0.965	0.82
AE	0.10	0 .9713	0.746
EE	0.11	0.897	0.62

Source: Computed from Field Survey Data, 2018/19

Sources of Economic Inefficiency

Before using all proposed socioeconomic and institutional variables in the model, a test for multicollinearity using VIF (1.14) technical inefficiency is essential. Accordingly, the VIF result of each variable is below, indicating no severe multicollinearity problem. The null hypothesis accepted based on the Breusch-Pagan test result of heteroskedasticity. Based on the Breusch-Pagan test result, heteroscedasticity also has no problem (Prob>chi2 = 0.1671).

The significant sources of technical, allocative, and economic inefficiencies (Table 7) are discussed. Among the 11 explanatory variables, six were statistically significant, and the remaining variable explanatory variables were insignificant.

Table 7: Determinants of technical, allocative, and economic inefficiencies of maize production

Variables	**Technical inefficiency**		**Allocative inefficiency**		**Economic inefficiency**	
	Coef.	Std Err	Coef.	Std Err	Coef.	Std Err
Age	0.0051	0.0039	0.001	.0025	0·001	0.0001
Sex	-0.0088*	0.0064	-0 .04*	0.720	-0.01*	0.001
Experience	-0.0014**	0.00126	-0.01*	0.002	-0.001*	0.01
Education	-0.435**	0.0600	-0.03*	0.01	- 0.001*	0.002
Livestock ownership	0.008	0.040	0.008	0.219	-0.002	0.03
Owen land	-0.017**	0 .14	-0.054*	0.003	-0.01*	0.001
Distance to extension center	0.0001	0.0007	0.0001	0.0115	0.001	0.01
Credit	0.002	0.01	0.0207	0.0.39	0.002	0.15
Cooperative	-0.07**	0.013	-0.007*	0.05	-0.4*	0.06
Off-farm	0.0468	0.04-	0.022	0.01	0.002	0.01
Training	-0.08**	0.002	-0.099*	*0.062	-0.002*	0.0012
Constant	0.023	0.045	2.1	2.45	0.35	0.47

Source: Computed from Field Survey Data, 2018/19

The education level significantly and negatively affects technical, allocative, and economic inefficiency at 5, 10, and 10 % significance levels, respectively. This might be due to education enabling producers to have a more remarkable ability to understand, adapt, and correlate inputs with lower costs and minimize input misuse. According to Huffman (1980), the relationship between education level and efficiency is theoretically justified as education increases performing capacity and so the best match of resources; because education is a proxy for managerial ability. This is similar to the results found by Kassa (2017), Asefa (2011), Mohammed (2012), Kitila and Alemu (2014), and Wassie (2012). In addition, the result of allocative and economic inefficiencies obtained in this study is in line with the results of Otitoju and Arene (2010), Asefa (2011), and Mohammed (2012).

The experience of maize producers negatively and significantly determine the technical, allocative, and economic inefficiency of maize production at 5, 10, and 10 % significance, respectively. This could be; because experience is a proxy for managerial aspects and improves the skill and technical capacity that enables best match inputs and in cost-saving parts to attain higher productivity at minimum cost. The technical inefficiency result is consistent with the results of Abdukadir (2010), Hidayah *et al.* (2013), Haile (2015), and Mekonnen *et al.* (2015). In regards to allocative and economic inefficiency, the result found is similar to the effects of Zalkuwi Dia et al. (2010), Hidayah et al. (2013), and Biam et al. (2016). However, it contrasts with the results of Mekonnen, Geta et al. (2015).

Smallholder maize producers' technical, allocative, and economic inefficiency were significantly and negatively determined by membership in the cooperative. Theoretically, membership in social organizations helps producers to achieve efficiency. But, this allocative inefficiency, the unexpected result could be that members might not discuss related to maize production while meeting and may spend more time discussing other issues that consume the time of maize farm operation. Besides, while producers want to take a loan from their cooperative, it takes more time, so they do not get their credit on their spending time until getting the loan consumes maize farm operating time.

Household participation in agricultural training is found significantly and negatively determine technical and economic inefficiency at 5 and 10% significance levels, respectively, but positively and significantly determine allocative inefficiency of maize production at a 10% significance level. The result found is similar to Tefaye and Beshir (2014)

The gender of the household head has a significant and positive effect on the maize production technical, allocative, and economic inefficiencies of smallholder farmers at 5, 10, and 10% significance levels, respectively.

The estimated results show that the land size of maize-producing households in the study area negatively and significantly determine the technical, allocative, and economic inefficiency of maize producers at the 5, 10, and 10% significance levels. Increased size of land owned leads to decrease inefficiency. This finding is in line with Masterson's (2007). However, it is in contrast with the results of Kitila and Alemu (2014).

CONCLUSIONS AND POLICY IMPLICATIONS

This study was conducted to estimate technical, allocative, and economic efficiencies and identify factors affecting efficiency among maize producer smallholder farmers in *Damote Woyede* District, *Wolita* Zone of southern Ethiopia. The result confirmed the efficiency of maize production and provided the opportunity to enhance the economic efficiency of smallholder maize producer households. The SPP and cost function indicate that the average TE, AE, and EE values of the sample households were 82%, 75%, and 62%, respectively. These results indicate that families can increase maize production by 18% without growing inputs if they are technically efficient. Furthermore, a cost minimization method can reduce the current input cost by 25%. Moreover, and increase maize production by 38% if they operate at complete technical and allocative efficiency levels.

Accordingly, in stochastic frontier production, the regression model revealed that the farmland, fertilizers, chemicals, seed, oxen power and family labour had a positive and significant relation with technical production. It also indicated that the cost function regression model revealed that the farm's land, fertilizer, chemical, family labour, seed, and oxen power had a positive and significant relation with allocative relation. The inefficiency source variables like sex of household, experience, education, land size, cooperative membership, and training had a negative and significant impact on technical, allocative, and economic inefficiencies. Therefore, AE can use the least-cost combination of inputs to produce a given output.

In general, an important conclusion from this study is that there is considerable room to reduce the technical inefficiency of maize production in the *Damote Woyede* district. Therefore, integrated development efforts that will improve the current level of input use and policy measures towards decreasing the inefficiency level will be paramount in improving maize production in the area. There is excellent potential for maize productivity to improve by utilizing the existing experiences of a few better-off smallholder farmers and demonstrating improved maize technologies. The positive and statistical significance of primary production inputs such as land, DAP or NPS, urea family, labour, and pesticides show the necessity of conventional inputs, showing better access and use of mentioned inputs could lead to higher maize production and productivity in the study area. Policy interventions should focus more on the timely supply of DAP or NPS, urea, and good quality of the improved seed to improve farmers' efficiency in the production of maize. Improving the educational level of smallholder farmers was also found to be taken into account in the minimization of economic inefficiency. It equips smallholder farmers with the necessary agricultural farming knowledge, thereby facilitating information dissemination regarding modern agrarian technology, input utilization, technical know-how, and recommended seed application that shifts their production frontier outward. Therefore, formal, and informal education/training activities in agricultural production must be provided for farmers to improve their economic efficiency in maize production.

Furthermore, the study has shown that access to credit improves economic efficiency. Credit is important to empower smallholder farmers to purchase inputs they cannot afford from their resources, enhancing the production and productivity of maize. Hence, to improve the economic efficiency of smallholder farmers for the revival of agriculture through credit accessibility, there must be access to credit institutions near the farm and a reduction in the interest rate and collaterals of banks on loans which will give confidence in credit accessibility to smallholder farmers. The higher economic inefficiency in the study area indicates that integrated development efforts that will improve the current level of input use are required. The cost minimization policy measures that will decrease the inefficiency of smallholder farmers will also significantly improve the living standard of smallholder farmers. Given the limited resources, it would be wise and better for the government and other concerned parties (like NGOs) to participate in developmental activities to encourage development endeavors towards improving the efficiency of smallholder farmers in the study area compared to the introduction of new technologies. However, the continuation of technology development and its dissemination is indispensable. Therefore, both ways of increasing productivity must be followed, although priority should be given to the efficiency of inefficient smallholder farmers.

Data Availability

The data for this research will be available upon request from the corresponding author.

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