INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 24, No. 3, p. 80-96, 2024
http://www.innspub.net

RESEARCH PAPER | OPEN ACCESS

Analysis of efficiency of maize production: The case of smallholder farmers in Shashogo District, Hadiya Zone Snnpr Region, Ethiopia

Dejene Tumiso, Abebe Markos*

Department of Economics, College of Business and Economics, Wachemo University, Ethiopia

Article published on March 11, 2024

Key words: Technical, Allocative and economic efficiency, Stochastic frontier model, Single stage estimation

Abstract

This study aims to identify major problems of maize production, to estimate the level of technical, allocative, and economic efficiency of maize production and to identify factors that contribute to efficiency differences among smallholder farmers in the shashogo district. It was based on cross-sectional data collected from 324 maize producer farmers through a multi-stage sampling technique during the 2021 production season. The technical, allocation, and economic efficiency of sampled farmers in maize production was estimated and analyzed by Cobb-Douglas functional form in the stochastic frontier model (SFM) with a single stage estimation method. The results show that the mean technical, allocative and economic efficiency score was found to be 73.49, 72.4 and 55.27%, respectively, indicating a substantial level of inefficiency in maize production. The result indicated that important factors that affected technical, allocative and economic efficiency are education, experience, soil fertility, extension visits, planting method, livestock holding, and off-farm/non-farm activity, land fragments, credit, and livestock holding,. Based on the findings the following recommendations are forwarded. The government and other concerned bodies should focus on establishing and encouraging rural microfinance, savings, and credit institutions and emphasize strengthening the existing agricultural extension service provision, need to have a soil fertility maintenance program, and extension workers can play a great role in improving the status of the soil by working closely with the farmers, establish farmer-training centers and/or model farmer plots to do practical demonstration work and due attention should be given to enhance the efficiency of farmers with large land holding size.

***Corresponding Author:** Abebe Markos ✉ marksawabe2023@gmail.com

Introduction

Agriculture is the central power of the Ethiopian economy. However, poor use of modern inputs such as fertilizers, improved seeds, and extension services has had a negative impact on its performance, which partly explains the sector's lower productivity; additionally, there is internal inefficiency among farmers in using available agricultural resources such as land and labor, which helps to improve efficiency and productivity (Milkessa and Mitiku, 2019). Efficiency is the most vital factor for increasing overall food security and decreasing poverty, particularly in major food crop potential areas of the country (Tesema *et al*., 2019).

The presence of inefficiency not only limits the gains from existing resources but also reduces the benefits that could arise from the use of improved inputs. Hence, enhancement in the level of efficiency could improve productivity by enabling farmers to produce the maximum possible output from a given level of inputs with the existing level of technology (Endrias *et al*., 2017) and (Sisay *et al*., 2015).

When there's inefficiency, attempts to introduce new technology would not have the expected impact because the prevailing knowledge is not efficiently utilized (Wana and Sori, 2020). With the rapid increase in the population, the demand for maize production has been enhanced, but productivity was not in a position to meet the higher demand for it. The problem can be solved by adopting improving technologies, increasing the use of improved technologies, and improving the efficiency of farmers at given inputs and technologies. However, improving the efficiency of farmers at a given input is less costly than adopting and increasing improved technologies in Ethiopia and the study area. Then the productivity of maize can be improved if factors that affect the efficiency of farmers are identified (Shiferaw, 2020). However, the efficiency of farmers itself is determined by different natural, social, and economic factors that are other responsible factors for maize as well as crop productivity (Zewdie Habte, 2020).

The available studies on the efficiency of cereal crops in general and maize production in particular in Ethiopia indicated the presence of inefficiency in maize production (Abate *et al*., 2019; Bealu Tukela, 2021; Dessale, 2021; Endrias *et al*., 2017; Geffersa *et al*., 2019; Kifle Degefa, 2017; Kusse Haile, 2018; Mustefa Bati, 2020; Shiferaw, 2020; Tekalign, 2019; Wassihun *et al*., 2019) in comparison with the international standards and most of them focused on technical efficiency. Even though it is by improving, the overall efficiency major gains in the production of maize can be achieved. Hence, this study aimed to examine the importance of both allocative and economic efficiency, in addition to technical efficiency, on the performance of maize production. Moreover, the previous researchers used Tobit, two-limit Tobit, and OLS to identify the determinants of efficiency. Unlike the previous researchers, this study used a stochastic frontier model with maximum likelihood estimation to identify determinants of efficiency in the study area.

Maize is among the major food crops widely produced and consumed by smallholder farmers in Ethiopia in general and in the Shashogo district in particular. The Shashogo district is one of the districts in the Hadiya zone, which is known for maize production. The average productivity of maize is about 30 quintals per hectare in some parts of the study area and 25 quintals in other parts, which is below average national as well as regional productivity levels. Due to the high population density in the district, this productivity level is not enough to feed the district's population (SDARDO, 2021).

Among the cereals grown in the study area, maize is the major crop in terms of volume of production and area cultivated. It is also the major source of staple food for the farmers among the crops grown in the area. Thus, due attention should be given to strengthening the productivity and efficiency of maize. In the study area, the productivity of the farmers has been low because of inefficient production and efficiency differences among producers. However, no research has been conducted on the efficiency of smallholder maize producers in the study area. Hence, there is a need to fill the existing knowledge gap by addressing issues related to the efficiencies of smallholder farmers' maize production in the study area and providing empirical evidence on smallholder resource use efficiency. Therefore, this study would fill the gap by focusing on the analysis of the overall efficiency of maize production in the study area.

Materials and methods

Types and sources of data

Both quantitative and qualitative types of data were collected from both primary and secondary data sources for the study. Primary data was collected by using an interview questionnaire, specifically a structural questionnaire on a variety of respondent demographic characteristics and socio-economic variables. The survey schedule was designed in such a way as to capture the necessary information on household-level livelihood indicators and demographic and socio-economic variables based on the objective of the study. The study was also supplemented by secondary data sources like reports of CSA, FAO, different journals, unpublished materials, and data from the agricultural development office.

Methods of data collection

Primary data was collected through personal interviews by using data collection instruments and questionnaires with structured interview schedules. The questionnaire includes questions about the farmer's demographic and other characteristics, farm characteristics, institutional factors, input types, resource endowment and input amount used, and output obtained by sample households over the course of the maize production season.

Before data collection, the enumerators were trained on how to collect data from sample households using structural questionnaires through interviews. The household questionnaire was first pre-tested to select maize-producing farmers, and appropriate modifications were made based on pre-tested results before actual data was collected. Then, the enumerators, under the supervision of the researcher, collect the data from the selected sample of maize-producing farmers.

Sampling technique and sample size

Multi-stage sampling techniques were used to attain accurate cross-sectional data from sample households in the study area. In the first stage, the Shashogo district was purposefully selected because of the presence of a large number of maize producer households and the extent of production in the area. Even though the study district comprises 34 rural kebeles, only 14 have a higher potential for maize production based on accessing good information within the district agricultural service officers, who consist of all those involved in maize production.

In the second stage, among those kebeles, five rural kebeles were selected using simple random sampling. Those kebeles are Jamaya, Bacha Gola, Shayambe, Shamshamise, and Dada. In the third stage, 328 samples of maize-producing farmers were selected by a simple random sampling method from 1833 maize producers from those kebeles (SDARDO, 2022). Since kebeles differ in terms of the total number of sample households they encompass, the probability proportional to the sample size-sampling technique was employed to determine the number of households from each kebeles.

The sample size was determined by the following simplified formula provided by Yamane (1967). This formula was used to calculate the sample size from a given population at a 95% confidence level and a 5% precision level. Accordingly, the sample size was estimated as follows:

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

Where n is the sample size,

N = the total number of households in the selected Kebeles (1833)

e = acceptable error margin (0.05)

Then the total sample size can be calculated by using the above formulas.

$$n = \frac{1833}{1+1833(0.05)^2} = 328$$

Consequently, 328 Maize producing farmers were used as a representative sample for the study, and this is considered third-stage sampling.

Data analysis

To achieve the objectives of the study, all descriptive statistics, inferential statistics, and econometric analyses were used. Descriptive statistics would be used to measure central tendency and measures of dispersion and to summarize some important characteristics like likelihood ratio and the chi-square (χ^2) test would be used to infer the population by using a sample. Under econometric analyses, the stochastic frontier production and efficiency model would be employed to measure the level of technical, allocative, and economic efficiency and identify determinants of efficiency with the single-stage estimation method.

Specification of the econometric model

The paper of Farrell, (1957) led to the development of numerous approaches to analyzing productivity and efficiency (Abdul-Salam and Phimister, 2015). There were two common methods used in the literature Stochastic Frontier Analysis (SFA) and Data Envelope Analysis (DEA). According to Toma *et al.* (2017), both methods achieve highly correlated results. The stochastic frontier approach was proposed by Aigner *et al.* (1977) and Meeusen and van Den Broeck (1977), later modified by (Jondrow *et al.*, 1982). The potential for the misspecification of functional form resulting in biased estimates of inefficiency is considered to be a weakness of the stochastic frontier approach relative to nonparametric approaches such as DEA. The DEA technique first introduced by Farrell, (1957) and further developed by Charnes *et al.* (1978) employs a nonparametric approach to estimate efficiency.

However, the most limitation of this system as underscored within the literature is that it ignores the effect of stochastic error and ascribes all deviation from the frontier to inefficiency (Kopp and Smith, 1980; Thiam *et al.*, 2015). Moreover, the non-inclusion of a disturbance term makes it difficult to perform statistical tests.

Agricultural production (typically rain-fed) is usually exposed to shocks like weather and climate risks, the incidence of pests and diseases, and other downside risk measures. Furthermore, because many farmers are smallholders whose farm operations are managed by family members, keeping accurate records is not always a priority. Thus, much of the data available on production is likely to be subject to measurement errors (Coelli and Battese, 1996).

Ignoring this and attributing it all to inefficiency may be a strong assumption with an opportunity to bias our analysis. Thus, this study adopted the SFA in estimating the efficiency of maize farmers in the study area since it differentiates deviation from the frontier into the two components of inefficiency and idiosyncratic error. The general stochastic frontier model in which an additional random error is added to the non-negative random variable is specified as follows:

$$y_i = x_i\beta + v_i - \mu_i, i = 1, 2 \ldots\ldots\ldots\ldots\ldots\ldots = N$$

Several functional forms have been developed to measure the physical relationship between input and output. The most common functional forms are the Cobb–Douglas and transcendental logarithmic (Translog) functions, each having its merits and demerits. Both models dominate the stochastic frontier and econometric inefficiency estimation applications literature (Coelli, 2005).

For this study, Cobb-Douglas functional form was selected based on a log-likelihood test result.

The log-linear form of the Cobb-Douglas production function mathematically can be formulated as:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{n} \beta_j x_{ij} + v_i - u_i, i = 1,2, \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots, = n$$

Where ln denotes the natural logarithm; j represents the number of inputs used; i represents the i^{th} farm in the sample; Y_i represents the observed maize output of the i^{th} sample farmer;X_{ij} denotes jth farm input variables used in maize production of the i^{th} farmer; β stands for the vector of unknown parameters to be estimated. The symmetric component (V_i) captures statistical noise and is assumed to be independently and identically distributed as $N \sim (O, \sigma^2 v)$.

Dennis Aigner *et al.* (1977) proposed the log-likelihood function for the model in equation (1) assuming half normal distribution for the technical inefficiency effects (u_i). They expressed the likelihood function using lambda (λ) parameterization, where λ is the ratio of the standard errors of the non-symmetric to symmetric error term (i.e. λ = σ^2ui/σ^2vi). However, according

(Battese and Coelli, 1995), proposed that the γ parameterization, where λ²/ (1+λ² to be used instead of λ. Because the value of λ could be, any non-negative value while γ ranges from zero to one and better measures the distance between the frontier output and the observed level of output resulting from technical inefficiency. There is an association between gamma (γ) and lambda (λ) which can be written as:

γ= [λ²/ (1+λ²]

These lambda, gamma, and represent are variance parameters in the model which value can estimate by ML.

The parameter γ (gamma) measures the difference between the frontier and observed levels of output and can be interpreted as the total variation in output from the frontier attributable to technical inefficiency. It has a value between zero and one. The value of zero implies that the non-negative random variable, u_i (inefficiency) is not present in the model and the value of one shows the absence of statistical noise from the model hence a low level of actual output compared to the maximum output of the other farm, which is a result of the inefficiency of smallholder farmers.

In this study, the likelihood ratio test was used to select the appropriate functional form that best fits the data, the appropriate distributional assumption of the efficiencies, the existence of inefficiency or not on the model, and others. Then, the number of hypothesis tests was run in this study using the likelihood ratio test, which gives in the following equation.

LR = λ= -2 ln [L (H0) / L (H1)]

λ= -2[ln L (H0) –ln L (H1)]

$$\sigma^2 = \delta_v^2 + \delta_u^2$$

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

Where, λ is the likelihood ratio (LR),

L (H0) = the log-likelihood value of the null hypothesis;

L (H1) = the log-likelihood value of the alternative hypothesis; and ln is the natural logarithms.

σ^2: is the total variance of the model and the term represents the ratio of the variance of inefficiency's error term to the total variance of the two error terms defined above. The value of the variance parameter ranges between zero and one.

The value of the likelihood ratio was compared with the significance level of 1 percent, 5 percent, and 10 percent with the point for the χ2 distribution, and the decision was made based upon the model result of LR and the critical value of χ2 distribution within the given degree of freedom. If the computed value of the test is larger than the critical value, the null hypothesis was rejected and the Translog frontier production function would better represent the production technology of farmers.

Empirical model specification

Stochastic production frontier model

The model of Cobb-Douglas production functional form used is specified as:

$$lnY_i = \beta_0 + \beta_1 lnseed + \beta_2 lnNPS + \beta_3 lnUrea + \beta_4 \ln Labor + \beta_5 \ln Oxen + \beta_6 \ln land\ size + \beta_7 + v_i - u_i.$$

Where *ln* denotes natural logarithm, Y_i is the output in kgs per hectare, β_0 represents intercept, β_i are unknown production function parameters. (v) is intended to capture the effects of the stochastic noise and is assumed to be independently and identically distributed, which is expressed by N(0,~σ^2v²). (u_i) is a non-negative random variable assumed to account for technical, allocative, and economic inefficiency in production and identically distributed as half-normal, Un (0,~σ^2u.)

Stochastic cost frontier model

From the duality nature of production and cost functions, the self-dual cost function can be specified as (Londiwe Thabethe, 2014).

$$lnCost = \alpha_0 + \alpha_1 lncostseed + \alpha_2 lncostNPS + \alpha_3 lncostUrea + \alpha_4 lncostlabor + \alpha_5 lncostOxen + \alpha_6 lncostland + v_i - u_i$$

Where ln is the natural logarithm, α_i are unknown cost function parameters and v_i,u_i are defined as earlier.

Factors affecting efficiency of maize farmers

After the scores of TE, AE, and EE of each farmer were estimated by using the stochastic frontier production and cost function, factors affecting TE, AE, and EE of maize production were identified and analyzed. To identify the determinants of maize farmers' efficiency, a stochastic frontier model with maximum likelihood estimation was used.

The following are efficiency parameters

$$Z_i = \beta_0 + \beta_1 Sex + \beta_2 Age + \beta_3 Edu + \beta_4 Fert + \beta_5 Offam + \beta_6 Lives + \beta_7 Fams + \beta_8 Frag + \beta_9 Prox + \beta_{10} Credit + \beta_{11} Exten + \beta_{12} Dista + \beta_{13} Farmsize + \beta_{14} exprience + \beta_{15} Hazard + \beta_{16} Planting + \varepsilon_i$$

Where Z_i is the dependent variable (Efficiency Scores of technical, allocative, and economic efficiency range between 0 to 1). The subscript i indicates the i^{th} household in the sample; μ_i is the technical, economic, and allocative efficiency score; β_i is a vector of parameters to be estimated; ε_i is the error term.

Definition of variables and their expected sign

Hypothesized variables of the production function and efficiency variables and their expected sign are presented in Table 1 and 2.

Table 1. Hypothesized variables of the production function

Name of Variables	Measurement	Notation	Expected sign
Area of land used for maize production	Hectare	Land	+
Seed used for maize production	Kilograms	SEED	+
NPS fertilizer used for maize production	Kilogram	NPS	+
Urea is used for maize production	kilograms	UREA	+
Oxen power used for maize	Oxen-days	OXEN	+
Labor used for maize production	Man-labor	LABOR	+

Table 2. Efficiency variables and their expected sign

Dependent variable				
TE, AE, AE	Continuous	SFM	Technical, allocative, and economic efficiency, scores of each farmer	
Independent variable				
Explanatory variables	Type	Measurement	Description	Expected sign
Age	Continuous	Year	Age of the household head	+ve
Gender	Dummy	Male=1, Female=0	Gender of the household head	+ve
Education	Continuous	Number of grades	The education status of the household head	+ve
Family size	Continuous	Number	Total number of persons in the household head in man equivalent	+ve
Experience	Continuous	Years	Farming experience of household head on maize production	+ve
Extension visit	Continuous	Number	Frequency of extension visit	+ve
Distance to market	Continuous	Kilometers	The distance of HHH residents to input and output market	-ve
Plot proximity	Continuous	Kilometers	The distance between HHH residents and the cultivated area for maize production	-ve
Access to credit	Dummy	Yes=1,No=0	Access to credit during the maize Production season	+ve
Livestock	Continuous	TLU	The total LH by farmers in maize production season	+
Poff/nonfarm activity	Dummy	1,if participat off/non-farm activity and 0,otherwise	This refers to the participation of sampled household in different activities outside his farm during the production season.	+/-
Soil fertility	Dummy	Fertile=1, Infertile=0	Fertility status of soil allocated for maize production	+
Fragmentation	Continuous	Number of parcels	It indicates the number of the parcel of land occupied by maize production	-
Farm size	Continuous	Hectare	Farm size of the household cultivated for maize production	+
Planting method	Dummy	1,if row planting 0,broadcast planting	It refers to planting activity in maize production	+
Hazard	Dummy	1, if the perceived, 0, not perceived	It refers to the hazard perception of households during maize production	-

Result and discussion

Econometric analysis

Hypothesis testing

Before discussing parameter estimates of production frontier function and the inefficiency effects, it is advisable to run several hypotheses tests to choose an appropriate model for further analysis and interpretation. The following hypotheses can be tested using the generalized likelihood ratio test: $LR = -2[L(H0) - L(H1)]$, where $L(H0)$ and $L(H1)$ are the values of the log-likelihood function under the null and alternatives hypothesis respectively (Gujarati, 2004).

The first hypothesis related to the appropriateness of the Cobb-Douglas functional form in preference to the Translog model. To select the appropriate specification, both Cobb-Douglas and Translog functional forms were estimated. The calculated log-likelihood Ratio (LR) is equal to 132.75 and the critical value of χ^2 at 21 degrees of freedom is 38.93. The computed LR statistic was less than the tabular value at a 1 percent significance level. The null hypothesis estimation results of different functional forms of stochastic production functions were accepted by indicating that the Cobb-Douglas functional form is a better representation of the data. These showed that the coefficients of the interaction terms and the square specifications of the input variables under the Translog specifications were not different from zero. Hence, the cobb-Douglas functional form was used to estimate the efficiencies of the sample farmers in the study area.

The next hypothesis is a test for adequacy of representing the data using SPF over the traditional average response function (OLS). The null hypothesis, of $H0\colon \gamma = 0$, specifies that the inefficiency effects are absent from the model (that is all maize producers are fully efficient). Whereas, the alternative hypothesis, $H0\colon \gamma > 0$, states that there is inefficiency in the production of maize during the 2021 production season. If this null hypothesis is not rejected, the SPF is equivalent to the convectional production function that is estimated by OLS. In this case, if there is an output difference among farmers given equal inputs, this difference is purely due to the difference in random shocks that are outside of the control of the farmer. This hypothesis can be tested using the generalized likelihood ratio test based on the value of the log-likelihood function under OLS and maximum likelihood estimation (MLE) under SFM or another testing method by obtaining the value of gamma from the ratio of the non-symmetric square to both symmetric and non-symmetric error term squares or by using equation (13), the if the gamma value becomes zero, failure to reject the null hypothesis (H0) and if gamma becomes greater than zero then the null hypothesis is rejected. Therefore, this study uses the last method of testing. As (Table 3) shows, the gamma value is 0.88, which is greater than zero. This implies that 86% of the total variation in maize yield among sample farmers is due to technical inefficiency. Therefore, there is room for increasing the production of maize in the study area by improving the technical efficiency of farmers at the current input and technology level. Hence, the null hypothesis is rejected, as a result, the production of maize in the study area is characterized by technical inefficiency or that not all maize producers are fully efficient. Thus, the data can be better represented by the stochastic production function than the average response function.

Table 3. Maximum-likelihood estimates of the Cobb-Douglas SPF model

Estimation of Maximum-likelihood of the Cobb-Douglas SPF model

Variables	Coef.	Std. Err.	z	P>|z|
Constant	5.419453***	0.2187576	24.77	0.000
Lnland	0.3769746***	0.0376721	10.01	0.000
Lnlabor	0.1763805***	0.0409009	4.31	0.001
Lnseed	0.084238***	0.0263673	3.19	0.006
Lnnps	0.1741318***	0.0637797	2.73	0.001
Lnurea	0.0251402	0.0522673	0.48	0.631
Lnoxen	0.372291***	0.0514291	7.24	0.000
Variance parameter				
Sigma_v	.171093	Lambda |	2.529943	
Sigma_u |	.4328555	Gamma	0.86	
Sigma2 |	.2166367	Log likelihood value	-72.205647	

***Implies significance at a 1 percent level of significance

Table 4. Hypotheses test for parameters of the stochastic production function

Hypotheses test

Hypothesis	df	LH0	LH1	Calculated X^2	Critical value	Decision
1. Production Function is Cobb-Douglas H0: C D ($\beta_7 \dots \dots \beta_{27} = 0$ H1=Translog production Function	27	-72.205647	-5.8328985	132.75	46.963	Accept
2. There is no inefficiency Component ($H_0 : \gamma = 0$)						
3. The coefficients inefficiency model equals zero $H_0 : \delta_0 \dots \delta_{16} = 0$	16	-221.31739	-72.205647	298.22	32.000	Reject

The third hypothesis is that the explanatory variables in the efficiency effect model are simultaneously equal to zero, $H0{:}\delta_0 = \delta_1 = - - - - - - - - - - \delta_{16} = 0$.

To test this hypothesis log- the likelihood ratio is calculated using the value of the log-likelihood function under the Cobb- Douglas stochastic frontier model (a model without explanatory variables of inefficiency effect model, H0) and the full frontier model (a model with all explanatory variables that are assumed to determine technical, allocative and economic inefficiency of each farmer, H1). The calculated value of LR equals 298.22 while the critical likelihood ratio (χ^2) of 1 percent of significance at 16 degrees of freedom equals 32 (Table 4). Since the calculated likelihood ratio, LR, value is greater than the critical value of LR, χ^2 at 16 degrees of freedom with an upper 1 percent level of significance, the null hypothesis that determinant variables in the inefficiency effect model are simultaneously equal to zero is rejected inefficiency effect model are jointly different from zero. This test confirms that there was an efficiency difference among the farmers due to inefficiency variables.

Therefore, the explanatory variables associated with the inefficiency effect model are jointly different from zero. It indicates that the joint estimation of the explanatory variables has a significant impact on technical efficiency. As a result, these variables jointly explain efficiency differences among the maize producer farmers in the study area during the 2021 production year.

Parameter estimates of the SPF model

Allowing for the estimates of frontier production where the farmers' production technology is represented by Cobb-Douglas production estimation was made using a single-stage estimation procedure for both parameters of SFM and efficiency model.

The model consists of 22 parameters; among these six of them are factors of production for maize (input variables), and the frontier production function, and 16 are associated with the explanatory variables influencing the level of technical, allocative, and economic efficiency. From the Cobb-Douglas stochastic frontier production function, the estimate of the variance ratio (γ) is significant. The value is 0.86. This indicates that about 86% of the variation in maize output is because of technical efficiency differences among production units. The high value of γ suggests that there are differences in technical efficiency among the production units considered in this study.

Land: is allocated for maize production, and it is found to be statistically significant at a 1% significance level, implying that increasing the level of these inputs would increase maize output in the study area. Moreover, the coefficient for land used was 0.37, which implies that, ceteris paribus, a 1% increase in the area of land allocated for maize production results in a 0.37% increase in maize output. This result is consistent with the findings of (Kifle Degefa, and MotiJaleta, 2017; Mustefa Bati, 2020; Shiferaw, 2020).

Labor: is a variable that is significant at a 1% level of significance with a p-value equal to 0.001 and its coefficient is positive, indicating that there is a positive relationship between maize production per hectare and the number of man hours employed for maize production. When other factors remain unchanged, a 1% increase in man-hours employed in maize production results in a 0.17% increase in maize output. This result is in line with the results of (Abate *et al.*, 2019; Mustefa Bati, 2020; Shiferaw, 2020).

Seed: This variable is significant at a 1% level of significance with a p-value equal to 0.006 and its coefficient is positive, indicating that there is a positive association between maize production per hectare and the amount of maize input used for maize production. The coefficient of maize seed used for maize production indicates that a 1% increase in the input used for maize production leads to a 0.08% increase in the maize output per hectare. This finding is in line with the findings of (Milkessa and Mitiku, 2019; Muluken Philipos Borko, 2021; Tesema *et al.*, 2019).

NPS (nitrogen, phosphorus, and sulfur): Maize is a crop that uses a lot of nitrogen and phosphorus for its growth. Therefore, fertilizer use is an important determinant of maize production. The application of NPS had a positive and significant influence on maize production at a 1% level of significance. As we can see from the SPF regression result, when other inputs remain unchanged if the application of NPS for maize cultivation increases by one percent, the production of maize is increased by 0.17%. This shows that farmers who apply higher rates of NPS receive a higher maize yield per hectare. This result is consistence with the findings of (Bealu Tukela Bekata, 2021; Milkessa and Mitiku, 2019).

Oxen: The highest coefficient of input of oxen, 0.436%, indicated that oxen were the main determinant input of maize production in the study area. As a result, maize production is relatively more sensitive to oxen utilization than other inputs. When other factors remain constant, a 1% increase in pairs of oxen hours used for maize production increases maize output by 0.37%. This result is in line with the findings of (Dessale, 2019; Edao and Gidey, 2021; Endrias *et al.*, 2017).

Estimation of the cost function

From the duality nature of production and cost functions and after estimating the frontier cost function, which is used to estimate allocative and economic efficiency, the following cost function was obtained (Table 5).

$$lnC_i = 2.04 + 0.39\ln\omega_1\text{land} + 0.49\ln\omega_2\text{seed} + 0.204\ln\omega_3\text{labor} + 0.095\ln\omega_4\text{NPS} + 0.03\ln\omega_5\text{urea} + 0.25\ln\omega_6\text{oxen} - 0.094\ln Y_i^*$$

Where: C is the per-farm costs of producing maize; $\omega_1$land is the observed seasonal rent of a hectare of land, $\omega_2$seed is the cost of seed per kilogram, $\omega_3$labor is the daily wage of labor, ω_4NPS is the cost of NPS fertilizer per kilogram, $\omega_5$urea is the cost of urea per kilogram $\omega_6$oxen are is the daily rent of oxen, Y^* is total maize output in Q_t of the i^{th} farm adjusted for any statistical noise,

Efficiency score and their distribution

Predicted farm-specific scores for technical, allocative, and economic efficiency scores among sampled maize farms in the study area are summarized in Table 6. The scores for technical and allocative efficiency were predicted after estimating the stochastic frontier production and cost functions, respectively, whereas the economic efficiency scores were computed as the product between TE and AE.

The average TE of 0.7349 suggests that an average maize farmer in the study area can still increase TE in maize production by about 26.51% to achieve the maximum possible level, while the most efficient one can increase output by 4.5%. Therefore, it shows that there is an efficiency gap and scope for improvement in maize production in the study area.

Table 5. Maximum-likelihood estimates of stochastic cost function model.

Estimation of Maximum-likelihood of stochastic cost function model

Variables	Coef.	Std. Err.	z	P>|z|
Constant	2.042***	.00812	24.29	0.000
lncostofland	.394***	.00303	48.56	0.000
lncostofseed	.049***	.00955	16.32	0.000
lncostoflabor	.204***	.01494	21.40	0.000
lncostofnps	.095***	.0120	6.39	0.000
lncostofurea	.039***	.0120	3.31	0.001
lncostofoxen	.256***	.01140	21.27	0.000
lnoutput	-.094***	.0840	-8.30	0.000
Variance parameter				
Sigma_v	.06521	Lambda	.0075102	
Sigma_u	.0004897	Gamma	.000056	
Sigma2	.0042526	Log likelihood value	424.8269	

*** implies significance at a 1 percent level of significance

Table 6. Statics of TE, AE, and EE

Summary statics of TE, AE, and EE

	Obs	Mean	Std. Dev.	Min	Max
TE	324	.7349	.140	.197	.955
AE	324	.724	.149	.173	.954
EE	324	.5527	.193	.034	.911

The results in Table 4, indicate that the average level of TE was 73.49%, which reveals that farmers on average could decrease inputs (land, oxen, labor, NPS, and seed) by 26.51% to get the output they are currently getting if they use inputs efficiently. The result also indicates that sample households in the study area were relatively good in TE than AE and EE (Table 6). In other words, it indicated that if resources were efficiently utilized, the average farmer could increase current output by 26.51% using existing resources and the level of technology. If the average farmer in the sample was to achieve the technical efficiency level of its most efficient counterpart, then the average farmer could realize 23.07% derived from (1-0.7349/0.9553)*100 increase in output by improving technical efficiency with existing inputs and technology.

Similarly, the mean allocative efficiency of farmers in the study area was 72.4% with a minimum of 0.173 and a maximum of 0.954 indicating that maize producer households could save 27.6% of their current cost of inputs if they use the right mix of inputs given their prices without reducing output levels, to reach the potential minimum cost level. Hence, a farmer with the average level of allocative efficiency would enjoy a cost saving of about 24.11% derived from (1 – 0.7243/0.9545)*100 to attain the level of the most efficient farmer.

As depicted in the (Table 6), following the relative ratio of the actual cost to the hypothetical minimum cost, EE could be obtained, which is the multiplication of TE and AE. Applying this procedure, this study found the mean economic efficiency level of sample households to be 55.27%, with minimum and maximum efficiency scores of 3.41% and 91.19%, respectively. The mean economic efficiency shows that an economically efficient household can reduce his/her maize production cost by 44.73%.

Factors affecting efficiency of smallholder maize farmers

The major interest behind measuring TE, AE, and EE levels is to know what factors determine the efficiency level of individual households. Then TE, AE, and EE estimates derived from the model were regressed on demographic, socioeconomic, farm, institutional, and environmental variables that explain variations in efficiency across farm households using the stochastic frontier model within ML estimation (Table 7).

Household head education (Edu) is expected to enhance the managerial and technical skills of maize producer farmers in the study area, and it is one of the important determinants of technical progress for maize production activity. The variable is used for making decisions regarding input choice and allocation, and he or she becomes active to manage other farm tools.

More educated farmers may have relatively adequate knowledge to apply improved methods to agricultural activities, and thus the farmers may be able to faraway themselves from being less technically, allocatively, and economically efficient than a less educated one.

Education was expected to make the farmers with better education technically, allocatively, and economically more efficient in maize production than those farmers with less or no education. As previously expected, the variable had a positive and significant effect on technical, allocative, and economic efficiency at a 1% level of significance, implying that more educated farmers are technically, allocatively, and economically more efficient than less educated farmers. The computed marginal effect indicated that as education level increases by one year, the probability of farmers being efficient technically, allocatively, and economically increases by 0.33, 0.35, and 0.51 percent, respectively, keeping all other variables constant at their mean value. As a result, educated farmers may be thought to have better access to agricultural information, be better at communicating with other leading farmers, and have a higher proclivity to adopt and use improved inputs (such as fertilizers and crop varieties) optimally and efficiently. This result is in line with the findings of (Ayele *et al.*, 2022; Edao and Gidey, 2021; Mustefa Bati, 2020).

Farming experience: It was expected that there would be positive contributions from specific experiences acquired by farmers, as they stay longer in the production of maize than less experienced ones. The findings show that the coefficient of farm experience was positive and statistically significant with respect to technical, allocative, and economic efficiency at a 1% significance level, as previously expected. This implies that farmers with more years of experience are better placed to acquire the knowledge and skills necessary for choosing appropriate new farm technologies over time. The computed marginal effect revealed that when farming experience increases by one year, the probability of farmers being efficient technically, allocatively, and economically increases by 0.196, 0.23, and 0.35 percent, respectively, while other factors remain unchanged. This result is consistence with the findings of (Bashe, 2021; Edao and Gidey, 2021).

Table 7. Maximum likelihood estimate for Technical, Allocative and Economic efficiency of maize production

	TE			AE			EE		
Variable	dy/dx	Std. Err.	P>|z|	dy/dx	Std. Err.	P>|z	dy/dx	Std. Err.	P>|z
Gender	.0094	.0084	0.264	.00246	.0102	0.808	.0102	.0123	0.406
Age	-.0002	.00038	0.590	-.00012	.0004	0.770	-.00013	.0005	0.813
Edu	.0033***	.001	0.002	.0035***	.0012	0.005	.0051***	.0015	0.001
Exper	.00196***	.0003	0.006	.0023***	.0007	0.003	.0035***	.0009	0.000
Famsize	.0016	.0034	0.622	.0011	.0038	0.765	.0023	.0048	0.624
Soilfert	.047***	.0104	0.000	.0473***	.0119	0.000	.0736***	.0155	0.000
Exten	.0056**	.0023	0.015	.0066***	.0025	0.009	.0087***	.0032	0.008
Planting	.0244**	.0106	0.022	.0308***	.0116	0.008	.0431***	.0154	0.005
TLU	.0035***	.0013	0.006	.0046***	.0016	0.004	.0069***	.0019	0.000
Offarm	.0280***	.008	0.001	.0293***	.0097	0.003	.0350***	.0117	0.003
Credit	.0276**	.0108	0.011	.0184	.0124	0.139	.0349**	.0160	0.029
Dista	-.0006	.0008	0.443	.00007	.0010	0.940	-.00044	.0012	0.720
Plotprox	-.0006	.0022	0.767	-.0021	.0025	0.416	-.0018	.0033	0.573
Landfra	-.0207***	.0048	0.000	-.0205***	.0057	0.000	-.0316***	.0071	0.000
Farmsiz	.0093*	.0055	0.094	.0102	.0064	0.111	.0194**	.0082	0.018
Hazard	-.006	.0077	0.430	-.0098	.0087	0.258	-.0141	.0110	0.199
lnsig2v	-7.11	.253	-6.861	.2859	-6.026	.2465			
lnsig2u	-4.349	.112	-4.101	.1185	-3.888	.1411			
sigma_v	.0285	.0036	.0323	.0046	.0491	.006			
sigma_u	.1136	.0063	.1286	.0076	.1430	.0100			
sigma2	.0137	.0013	.0175	.0018	.0228	.0025			
Lambda	3.978	.0085	3.975	.0107	2.912	.0145			

***, ** and *refers to the level of significance at 1%, 5% and 10% respectively

Soil fertility: As expected, soil fertility also had a positive and significant effect on technical, allocative, and economic efficiencies at the 1% significance level. This means that farmers who allocated fertile land for the production of maize were more efficient technically, allocatively, and economically than their counterparts (farmers who allocated no fertile or infertile land for maize production). This may be linked to those fertile lands that require less commercial application of fertilizer, which leads to cost reductions and reduces farmers' inefficiency. Furthermore, a change in the dummy variable infertile land to fertile land (0 to 1) increased the probability of the farmer being technically, allocatively, and economically efficient by approximately 4.7, 4.73, and 7.36 percent, respectively, another factor constant. This finding was agree with the findings of (Ayele *et al.*, 2022; Milkessa and Mitiku, 2019; Tenaye, 2020).

Extension contact: The coefficient of extension contact was positive and statistically significant with respect to allocative and economic efficiency at a 1% and technical efficiency at a 5% significance level as expected, suggesting that such frequency of extension contact increases farmers' efficiency since farmers can use modern techniques of maize production activity, including land preparation, planting, the application of organic and inorganic fertilizer, and the proper harvesting of maize output. The chance that farmers who have more extension visits are more important for modern agricultural input mobilization, input use, and disease control, which enables them to reduce inefficiency. Thus, increasing the frequency of development agents visiting farmers who produce maize is very important to providing effective agricultural extension services in the study area. The contribution of increasing the number and frequency of extension agent visits to farmers in the study area can help to close the gap between efficient and inefficient maize producer farmers. Such a situation stimulates farmers' adoption of agricultural technologies, which enables them to improve their efficiency level in maize production. Furthermore, the computed marginal effect result shows that, when extension visits increase by one day, the probability of farmers being technically, allocatively, and economically would increases by 0.56, 0.66, and 0.87 percent, respectively, keeping other factors constant. This finding was agree with the previous findings of (Ayele *et al.*, 2022; Tesema, 2021a).

Farm size: The coefficient of farm size in hectares was positively and statistically significant for technical and economic efficiency at a 10% and 5% significance level, respectively, as was expected. This shows that a household operating on a small area is less efficient than a household with a large land holding. This is primarily justified by the belief that farmers with larger farms can diversify their crops more effectively and have a better chance of planting maize on fertile soils. Additionally, farmers with a larger area of cultivated land have the capacity to use compatible technologies that could increase their efficiency. As a result, with increased farm holding size, the technical and economic efficiency of the farmer might increase. Further computed marginal effect results indicated that when the farm size of the farmers increased by one hectare, the probability of them being technically and economically efficient would increase by 0.93 and 1.94 percent, respectively, while other determinants remained constant. This result was consistent with the findings of (Edao and Gidey, 2021; Tenaye, 2020).

Livestock holding: The TLU as calculated by the conversion factor employed by (Strock, 1991). The number of livestock in the tropical livestock unit was expected to determine technical, allocative, and economic efficiency positively. The TLU is positive and statistically significant with technical, allocative, and economic efficiency at a 1% significance level, in accordance with the expectation. This implies that livestock can support maize production in many ways: cash from livestock sales can improve maize production for input purchases, supply draft power for farming, and produce manure that is used to maintain soil fertility. The results also show that farmers with the largest livestock holdings help shift cash constraints and meet all of the needs of farmers in the study area. Each unit increase in the value of TLU would increase the probability of a farmer being technical, allocative, and economic efficiency by 0.35, 0.46, and 0.69 percent, respectively; other factors would remain unchanged. This result was in line with the findings of (Shiferaw, 2020; Tesema, 2021a).

Land fragmentation: refers to the number of plots owned by the farmers, and it was expected to determine technical, allocative, and economic efficiency negatively. As with prior expectations, the findings show that the coefficient of fragmentation is negatively and statistically significant with respect to technical, allocative, and economic efficiency at a 1% significance level, as was expected because having more plots in the crops under consideration does not improve the level of efficiency of farmers. Land fragmentation causes an increase in boundary areas that are not planted, which decreases the operated farm area. In addition, low productivity occurs around boundaries because they lower the input application rate, serve as routes, and act as a cover for nearby grazing animals. Fragmented land causes inefficiency by reducing the availability of family labor, wasting time, and wasting other resources that should be available at the same time. Moreover, as the number of plots operated by the farmer increases, it may be difficult to manage these plots. In the study area, the land is fragmented and scattered in different places. Thus, farmers that have a large number of plots may waste time moving between plots. The marginal effect result shows that when other factors remain constant and fragmented land increases by one farm, the probability of farmers being technically, allocatively, and economically efficient would decrease by 2.07, 2.05, and 3.16 percent, respectively. This finding was agree with the findings of (Mustefa Bati, 2020; Tenaye, 2020).

Credit accesses: As the prior expected result also indicated, credit used had a positive and a statistically significant effect on technical and economic efficiency at a 5% level of significance. This suggests that, on average, households that use credit tend to reveal higher levels of efficiency. Credit availability can solve the problem of the cash constraint and enable the farmers to purchase agricultural inputs that they cannot easily obtain with their resources. Moreover, a change in the dummy variable representing the uses of credit by the household ordered from 0 to 1 would increase the probability of the farmers being technically and economically efficient by about 2.76 and 3.49 percent, respectively, other factors remain constant. This result was agree with the findings of (Shiferaw, 2020; Tesema, 2021b).

Participation in non/off-farm activity: It was expected that a farmer who participated in non-farm activity was more efficient than their counterparts. As expected, the coefficient of participation in off-farm or non-farm activity was positive and significant for technical, allocative, and economic efficiency at a 1% significance level. Participation in non/off-farm activities affects efficiency positively for the reason that the income obtained from such activities could be used for the purchase of agricultural inputs. The availability of non-farm income shifts the cash constraint outward and enables farmers to make the timely purchase of those inputs, which they cannot provide from on-farm income. Therefore, it enables farmers to maximize their output at an efficient cost of production. In addition, the computed marginal effect revealed, that a change in a dummy variable's participation in non-farm activity from (0 to 1) would increase the probability of the farmer being technically, allocatively, and economically efficient by about 2.80 percent, 2.93 percent, and 3.50 percent, respectively, keeping another factor constant. This result was agree with the findings of (Ayele *et al.*, 2022; Milkessa and Mitiku, 2019).

Planting method: The planting method had a positive and significant effect on technical, allocative, and economic efficiency at a 1% level of significance; this result was in line with expectation. This reveals that farmers who use row planting for maize production are more efficient than other farmers who use broadcast planting. This is because row planting reduces the amount of seed input and fertilizer required per hectare, improves the yield per hectare, and reduces the cost of inputs. The result of marginal effect indicated that a change in a dummy variable for row planting (0 to 1) would increase the probability of the farmer being technically, allocatively, and economically efficient by about 2.44, 3.08, and 4.31 percent, respectively, with another factor constant. This result was agree with the findings of (Shiferaw, 2020).

Conclusion

According to the findings of the study, the productivity of maize in the study area was 25.35 quintals per hectare, which was less than the 33.86 quintals per hectare of frontier output, the 41.79 quintals per hectare of national output, the 41.66 quintals per hectare of SNNPR, and the 43.31 quintals per hectare of Hadiya zone.

The technical, allocative, and economic efficiency of sampled farmers in maize production was estimated and analyzed by the Cobb-Douglas production functional form in the stochastic frontier model (SFM) with the single-stage estimation method. The estimated SFM indicated that input variables (land, labor, seed, NPS, and oxen) were found to significantly and positively influence maize production at a 1 percent level of significance. The production function of maize for the sampled farmer was characterized by an increasing return to scale (1.208).

As an estimation, the result shows that the mean technical, allocative, and economic efficiency level of maize producers was 0.735, 0.724, and 0.552, respectively, and their respective technical, allocative, and economic efficiency ranges from 0.140 to 0.955, 0.149 to 0.954, and 0.193 to 0.911. The estimated gamma (γ) parameter was about 0.86. On the farm, specific socio-economic and institutional factors hypothesized to influence the technical and economic efficiency of farmers in maize production (education, experience, soil fertility, extension visits, planting method, livestock holding, off-farm/non-farm activity, credit, farm size, land fragmentation at the 1 percent level of significance, and farm size at the 10 percent and 1 percent significance levels) have a positive influence. In addition, all the above variables except credit and farm size have a positive influence on allocative efficiency at a 1 percent level of significance.

Recommendation

As indicated in the study results, farmers face the problem of inefficiency in maize production. The study suggested that improvements in technical, allocative, and economic efficiency represent a greater opportunity for promoting maize production. The aforementioned factors have significant policy implications because they reduce farmers' existing level of inefficiency in maize production. Therefore, the following important policy recommendations were given based on the results of the study discussed below.

To reduce the existing level of maize production shortage, particularly in the study area and generally in Ethiopia, policymakers should focus not only on the opening and diffusion of externally supplied production-enhancing input, but also on improving the existing level of efficiency with the existing level of input by determining factors raising the inefficiency level and providing remedies. According to the results of the study, some recommendations were suggested to be addressed either by the government or by any other concerned body. These are:

1. A study result showed that education and TE, AE, and EE had a positive relationship with maize production; hence, an effort by the regional government towards increasing formal and informal schooling would be consistent and sustainable in this area so that farmers could use the available inputs more efficiently under the existing technology.
2. The positive effect of credit accesses on TE and economic efficiency needs financial strengthening together with awareness-creation efforts aimed at enhancing maize production in particular and crop production in general. This study recommended the availability of credit, which may capacitate the farmer to avoid financial shortage and the untimely selling of livestock and other agricultural output in the case of different financial obligations.

Therefore, the policymakers, government, and other concerned bodies should focus on establishing and encouraging rural microfinance, savings, and credit institutions and emphasize strengthening the existing agricultural extension service provision.

3. The positive influence of soil fertility on TE, AE, and EE implies that fertile soil increases the efficiency of farmers by reducing factors that reduce the soil fertility of maize plots. Finally, the farmers have to improve the land status by applying new fertility practices on their farm through improved land management practices and soil conservation practices. Policy makers also need to have a soil fertility maintenance program, and extension workers can play a great role in improving the status of the soil by working closely with the farmers in this regard.
4. Extension visit had a significant and positive effect on TE, AE and EE. Therefore, policies and strategies that provide improved extension visit and could help raise the efficiency of maize production should be consistent and developed more than in the current situation. Hence, the number of visits to households by extension agents should be increased through the subsequent training program. Moreover, given the multiple extension services, the expansion of basic and functional educational provisions in the rural area must be considered a key strategy for increasing the efficiency of smallholder households in the study area.
5. Participation in off-farm or non-farm activity has a positive impact on TE, AE, and EE, indicating income obtained from off-farm/non-farm activity could be used for the purchase of agricultural inputs because the availability of non-farm income shifts the cash constraint outward and enables farmers to make the timely purchase of those inputs, which they cannot provide from on-farm income. As a result, rather than spending their time idle, smallholder farmers should engage in nonfarm activities to supplement their income during the off-farm season.
6. Planting is one of the variables that is found to significantly affect the farmers' technical and economic efficiency in the production of maize in the district. However, until now, a significant number of the farmers in the study area had not adopted the row planting technology. As a result, the regional government or district bureau of agriculture should have a primary responsibility to maintain the provision of row planting awareness creation in these and other areas so that farmers can use the available inputs more efficiently under the current technology level. Moreover, this study recommends that the government and any concerned stakeholders establish farmer-training centers (FTC) and/or model farmer plots to do practical demonstration work.

References

Abate TM, Dessie AB, Mekie TM. 2019. Technical efficiency of smallholder farmers in red pepper production in North Gondar zone Amhara regional state, Ethiopia. Journal of Economic Structures. https://doi.org/10.1186/s40008-019-0150-6

Abdulai S, Nkegbe PK, Donkor SA. 2019. Assessing the Economic Efficiency of Maize Production in Northern Ghana **14**(1), 123–145.

Aigner D, Chu SF. 1968. On estimating the industry production function **58**(4), 826-839.

Alemu D, Mwangi W, Nigussie M, Spielman DJ. 2008. The maize seed system in Ethiopia: challenges and opportunities in drought prone areas. African Journal of Agricultural Research, 3(4), 305–314.

Asfaw. 2021. Analysis of technical efficiency of smallholder tomato producers in Asaita district, Afar National Regional State, Ethiopia. PLoS ONE **16**(9), 1-16. https://doi.org/10.1371/journal.pone.0257366

Barros CP, Mascarenhas MJ. 2005. Technical and allocative efficiency in a chain of small hotels. International Journal of Hospitality Management **24**(3), 415–436. https://doi.org/10.1016/j.ijhm.2004.08.007

Bashe A. 2021. Economic Efficiency of Wheat Production: The Case of Angecha District, Southern Ethiopia. 9(4).

Berhanu Gebremedhin, Fernandez-Rivera S, Mohammed Hassena WM, SA. 2007. Maize and livestock: Their inter-linked roles in meeting human needs in Ethiopia. Research Report 6. ILRI (International Livestock Research Institute), Nairobi, Kenya. 103p.

Charnes, Cooper R. 1978. Measuring the efficiency of decision making units. European Journal of Operational Research **70**, 1298–1322. https://doi.org/10.1016/j.rser.2016.12.030

Coelli. 2005. An introduction to efficiency an introduction to efficiency.

Coelli T, Battese G. 1996. Identification of factors which influence the technical inefficiency of Indian farmers. Australian Journal of Agricultural and Resource Economics, 40(2), 103-128. https://doi.org/10.1111/j.1467-8489.1996.tb00558.x

Corbo V, Meller P. 1979. The translog production function. Some evidence from establishment data. Journal of Econometrics **10**(2), 193-199. https://doi.org/10.1016/0304-4076(79)90004-6

CSA. 2021. Agricultural sample survey 2020/2021 volume 1-Reports on area and production of major crops (holdings, Meher seasons), Stastical Bulletin, Central Statistical Agency, Addis Abeba, Ethiopia.: Vol. I.

Dessale M. 2019. Analysis of technical efficiency of small holder wheat-growing farmers of Jamma district, Ethiopia. Agriculture and Food Security **8**(1), 1–8. https://doi.org/10.1186/s40066-018-0250-9

Edao A, Gidey G. 2021. Technical Efficiency of Malt Barley Production in Malga District of Southern Technical Efficiency of Malt Barley Production in Malga District of Southern Ethiopia. January. https://doi.org/10.7176/ISDE/12-1-03

EEA. 2017. EEA Research Brief Reducing The Maize Yield Gap In Ethiopia : Analysis And Policy Simulation Ethiopian Economics Association Research Brief No. 2, November 2017 (Issue 02).

Endrias G, Bogale A, Kassa B, Elias E. 2017. Productivity and Efficiency Analysis of Smallholder Maize Producers in Southern Ethiopia Productivity and Efficiency Analysis of Smallholder Maize Producers in Southern Ethiopia. Journal of Human Ecology ISSN: **9274**, 67–75. https://doi.org/10.1080/09709274.2013.11906554

FAO. 2018. Food Loss Analysis: Causes and Solutions. In Food Loss Analysis: Causes and Solutions - case studies in the Small-scale Agriculture and Fisheris Subsector (Issue May). http://www.fao.org/3/a-az568e.pdf

FAO. 2019. Crop and food securityAssesment Mission for Ethiopiaspecial Report of Food Agriculture Organization and World Food Programme. Rome, Italy.

Farrell. 1957. The Measurement of Productive Efficiency Author (s): M. J. Farrell Reviewed work (s): Source : Journal of the Royal Statistical Society. Series A (General), Vol. 120, No. 3 (1957), pp. Published by : Wiley-Blackwell for the Royal Statistica. **120**(3), 253-290.

Fufa B, Hassan RM. 2006. Determinants of fertilizer use on maize in Eastern Ethiopia: A weighted endogenous sampling analysis of the extent and intensity of adoption. Agrekon **45**(1), 38–49. https://doi.org/10.1080/03031853.2006.9523732

Gebre GG, Isoda H, Rahut DB, Amekawa Y, Nomura H. 2021. Gender differences in agricultural productivity: evidence from maize farm households in southern Ethiopia. GeoJournal **86**(2), 843–864. https://doi.org/10.1007/s10708-019-10098-y

Gujarati DN. 2004. Basic Economettrics. In The McGraw-Hill.

Ibrahim FD, IUN. 2018. Influence of Agricultural Technology Utilization. **3**(March), 162–171.

Jondrow J, Knox Lovell CA., Materov IS, Schmidt P. 1982. On the estimation of technical inefficiency in the stochastic frontier production function model. Journal of Econometrics **19**(2-3), 233-238. https://doi.org/10.1016/0304-4076(82)90004-5

Kifle Degefa, MotiJaleta BL. 2017. Economic Efficiency of Smallholder Farmers in Maize Production in Bako Tibe District, Ethiopia. Developing Country Studies **7**(2), 80–86.

Londiwe Thabethe EM, Marlene Labuschagne. 2016. Estimation of Technical, Economic and Allocative Efficiencies in Sugarcane Production in South Africa: A Case of Mpumalanga Growers. Journal of Economics and Sustainable Development **5**(16), 86–95.

Lovell CAK. 1993. Measurement of Productive Efficiency: Techniques and Applications. Journal of Econometrics **6**, 3-67.

Meeusen W, van Den Broeck J. 1977. Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. International Economic Review **18**(2), 435. https://doi.org/10.2307/2525757

Milkessa A, Mitiku EG. 2019. Economic Efficiency of Smallholder Farmers in Wheat Production: The Case of Abuna Gindeberet District, Western Ethiopia. International Journal of Environmental Science and Natural Resource **16**(2), 65-75. https://doi.org/10.15414/raae.2019.22.01.65-75

Muluken Philipos Borko. 2021. Technical Efficiency of Maize Production in MeskanWoreda of Gurage Zone Technical Efficiency of Maize Production in MeskanWoreda of Gurage Zone. https://doi.org/10.14662/IJEBM2020.125

Mustefa Bati JH. 2020. Economic Efficiency in Barely Production : The Case of Chole District , East Arsi Zone, Oromia National Regional State. Journal of Resources Development and Management **66**, 25–36. https://doi.org/10.7176/JRDM/66-03

Romy S. 2020. The drivers of maize area expansion in sub-Saharan Africa. How policies to boost maize production overlook the interests of smallholder farmers. Land **9**(3). https://doi.org/10.3390/land9030068

Sapkota M. 2021. Factors Associated with the Technical Efficiency of Maize Seed Production in the Mid-Hills of Nepal : Empirical Analysis. International Journal of Agronomy, 2021.

Shahidur, Negass A. 2013. Policies and performance of Ethiopian cereal markets. Food and Agriculture in Ethiopia: Progress and Policy Challenges **9780812208**, 123–158. https://doi.org/10.9783/9780812208610.123

Shiferaw. 2020. Analysis of technical efficiency in maize production in Guji Zone: Stochastic frontier model. Agriculture and Food Security **9**(1), 1–15. https://doi.org/10.1186/s40066-020-00270-w

Sisay D, Jema H, Degye G, Abdi Khalil E. 2015. Technical, allocative and economic efficiency among smallholder maize farmers in Southwestern Ethiopia: Parametric approach. Journal of Development and Agricultural Economics **7**(8), 282-291. https://doi.org/10.5897/jdae2015.0652

Spielman D, Mekonnen DK. 2017. Seed, Fertilizer and Agricultural Extension in Ethiopia. Journal of Applied Agricultural Economics and Policy Analysis, 2002.

Tadele M, Wudineh G, Ali C, Agajie T, Tolessa D, Solomon A, Tesfaye S. 2018. Technical efficiency and yield gap of smallholder wheat producers in Ethiopia: A Stochastic Frontier Analysis. African Journal of Agricultural Research **13**(28), 1407-1418. https://doi.org/10.5897/ajar2016.12050

Teferra B, Legesse B, Haji J, Kassie GT. 2018. Farm Level Efficiency of Crop Production in the Central Highlands of Ethiopia. American Journal of Rural Development **6**(2), 49–58. https://doi.org/10.12691/ajrd-6-2-4

Tekalign FM. 2019. Determinants of Technical Efficiency of Maize Production in Ethiopia : An Empirical Review. American Journal of Environmental and Resource Economics **4**(4), 144–151. https://doi.org/10.11648/j.ajere.20190404.15

Tenaye A. 2020. Technical efficiency of smallholder agriculture in developing countries: The case of Ethiopia. Economies **8**(2), 1-27. https://doi.org/10.3390/ECONOMIES8020034

Tesema T. 2021a. Analysis of Technical , Allocative And Economic E ciency In Maize Production In Ethiopia Evidence From Low Land of Gudeya Bila : Stochastic Frontier Approach. 0-18.

Tesema T. 2021b. Heliyon Determinants of allocative and economic efficiency in crop-livestock integration in western part of Ethiopia evidence from Horro district: data envelopment approach. Heliyon **7**(June), e07390. https://doi.org/10.1016/j.heliyon.2021.e07390

Thiam A, Bravo-Ureta BE, Rivas TE. 2015. Technical efficiency in developing country agriculture: A meta-analysis. Agricultural Economics **25**(2–3), 235-243. https://doi.org/10.1016/S0169-5150(01)00081-0

Edosa TT, Temesgen Kebede ZS. 2019. Analysis of Price Efficiency of Smallholder Farmers in Maize Production in Gudeya Bila District, Oromia National Regional State, Ethiopia : Stochastic, Dual Cost approach. International Journal of Contemporary Research and Review **10**(04), 21480-21487.

UNDP. 2018. Ethiopia's progress to warding eradicating poverty paper tobe presented to the inter-agemcy ggroupmeeting on the implimentation of the third united deade for the eradication of poverty (2018-2027). Adsis Abeba, Ethiopia.

Wana H, Sori O. 2020. Factors Affecting Productivity of Wheat Production in Horo District of Oromia Region, Ethiopia. Journal of Poverity, Investment and Development **52**, 1–13.

Wassihun AN, Koye TD, Koye AD. 2019. Analysis of technical efficiency of potato (*Solanum tuberosum* L.) production in Chilga District, Amhara National Regional State, Ethiopia. Journal of Economic Structures, 8(1). https://doi.org/10.1186/s40008-019-0166-y

Wijnands J, Biersteker J, Loo R. Van. 2009. Oilseeds business opportunities in Ethiopia 2009. Ministry of Agriculture, Nature and Food Quality, the Netherlands, January 2007, 1-33. https://www.researchgate.net/publication/40101884

World Bank. 2021. Toward Productive, Inclusive and Sustainable Farms and Agribusiness Firms: An Evaluation of the World Bank Groups Support for Development of Agrifood Economies (2010-20).

Zewdie Habte S. 2020. Agricultural policies, agricultural production and rural households' welfare in Ethiopia. Journal of Economic Structures, 9(1). https://doi.org/10.1186/s40008-020-00228-y