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Research Article

Analysis of farm households' price efficiency in the production of Maize: The case of Abobo District, Gambella Regional State, Ethiopia: An application of stochastic frontier analysis and dual cost approach

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Abstract

Even though agriculture is the backbone of the Ethiopian economy, its performance is unsatisfactory, and food production is very low compared with population growth. As the possibility of improving production by bringing extra resources into use became increasingly restricted, the efficiency with which the farmers use existing resources has received the utmost attention to block the gap between the supply and demand of food. However, price efficiency in maize production has not been extensively studied because previous studies mainly focused on economic efficiencies. This study was carried out to analyse the productivity and price efficiency of smallholder farmers in maize production in the Abobo district, Gambella Regional State, Ethiopia. To meet the objectives of the study, secondary data were used in addition to the primary data. The primary data were gathered via structured questionnaires from 152 randomly selected sample households during the 2023/24 production year, and secondary data were collected from different sources. Cobb-Douglas production function was applied to analyse the productivity, whereas the Tobit model was used to estimate farm households' price efficiency. The results of the survey showed that mean price efficiency was estimated to 70.9%, implying that there exist considerable levels of price inefficiencies in the production of maize in the study area. The Tobit model results revealed that livestock holding, frequency of extension contact, land fragmentation and off/non-farm activity had a considerable effect on price efficiency. The result of the study shows that there exists an opportunity to boost the efficiency of maize producers in the study area. In addition, policy measures derived from the results of the study include increasing the livestock production, strengthening the extension services, promoting off/non-farm activity and raising the resettlement programs in the study area.

KEYWORDS: Cobb-Douglas; Dual Cost; Price Efficiency; Stochastic frontier; Tobit

1 Introduction

Currently, the world population is increasing at an alarming rate. About 80% of the world's population depends on farming, live in rural areas and are almost poor. In the world, agricultural development is expected to can support in sinking down poverty. Maize (Zea mays L.) was domesticated from teosinte in Mexico, and it spread to the rest of the world in the 16th through 18th centuries. It is the most widely distributed and the first most important cereal crop followed by rice and wheat in the world ("FAOSTAT 2013," 2013; Njeru, 2010; Shiferaw et al., 2011). Africa is an agrarian continent whereby two-thirds of the people directly or indirectly engaged their livelihood depending on the agriculture sector. The Sub-Saharan Africa region accounts for more than 950 million people, approximately 13% of the global population (OECD/FAO, 2016).

Maize accounts for the calories and protein consumed in ESA and in West Africa. Aside from its staple food use, it makes a significant contribution to animal feed (especially poultry), biofuel and industrial uses (Ntabakirabose, 2017). In developed countries, 70% of maize is destined for feed, 3% is consumed directly by humans, and the remaining 27% is used for biofuels, industrial products, and seed. In Sub-Saharan Africa, 77% of maize is used as food and only 12% serve as feed. In Ethiopia, cereals are the major food crops both in terms of area coverage and volume of production (Haile et al., 2018).

The major cereal crops grown in Ethiopia are teff, maize, wheat, barley, sorghum and millet (Central Statistical Agency, 2007; Mustefa, 2014). Maize is one of the five major staple cereal crops in Ethiopia. Among the crops grown in Ethiopia, maize is the most significant cereal crop in terms of total production, area coverage, and better availability and use of new production technologies (Cochrane & Bekele, 2017). Maize is a major source of food and cash for smallholder farmers (Abdulai et al., 2018). It is the highly demanded food crop in the southwestern part of Ethiopia. High productivity and efficiency in maize production is critical to improve food security, reduce the level of poverty and achieve or maintain agricultural growth.

According to the Central Statistical Agency (2017) report, maize is cultivated on over 2.13 million hectares of land, with an annual production of 7.8 million tons with a yield of 36.75 qt/ha, contributing about 27.02% of the total cereal production in Ethiopia. In terms of area of production, maize stands second by covering 16.98% of the total cereal crop areas, followed by only teff (24.00%), followed by sorghum (14.97%) and wheat (13.49%). From the total cereal production, maize ranks first in the country. In the Gambella region, the total area covered by maize in the production year of 2023/24 was 4831 hectares and 125,828 quintals of maize was produced by 5.36 million smallholder farmers and the average productivity was 38.18 qt/ha (Tilahun et al., 2023). At the same time, there were 329,242 smallholders producing 4.6 million quintals of maize with a yield of 42.30 qt/ha from 108,914 ha of land in the Illubabor zone.

In the Abobo woreda, where this study was conducted, maize (Zea mays L.) production is the means of livelihood of the people to meet the household consumption and to generate income. However, to the knowledge of the researcher, there was no study conducted in the district before to identify whether the farmers are using the inputs in an optimal proportion, given input prices for maize production. Therefore, this study aimed to estimate the levels of price efficiency and to identify the major factors affecting it by collecting cross-sectional data from maize-producing smallholder farmers in the Abobo district.

2 Materials and methods

2.1 Description of the Study Area

The Abobo district is in the Gambella regional state of the Agnwa zone, Ethiopia. The Abobo district is one among the five woredas of the Agnwa zone. It is located 813 Km southwest of Addis Ababa and 47 Km south of Gambella, which is the capital of the region. Geographically, it lies between $07^{\circ}45'00''$ N to $08^{\circ}00'00''$ N latitudes and $34^{\circ}30'00''$ E to $34^{\circ}45'00''$ E longitudes. The woreda bordered with Gambella zuriya woreda to the north, Etang special woreda to the northwest, Goge woreda to the south, Jikawo and Jore woredas to the west, Mengeshi woreda and Oromiya Regional State to the east. It covers a total area of 361324.58. Km2 and has 16 rural kebele administration and one urban administration (Abobo Woreda Office of Finance and Economic Development (AWOFED), 2023; Central Statistical Agency, 2007).

The terrain of the woreda can be mostly characterized by a vast flat landscape and a slight plateau to the east. The altitude ranges from 460 to 1650 m.a.s.l. The major water bodies in the woreda include the river Alwero and Lake Alwero, which is an artificial one. The woreda has two agro-climatic zones. These are woinadega (10%) and Kolla (90%). Accordingly, the mean annual minimum and maximum temperature of the woreda ranges between $18^{o}C$ and $39oC$, respectively. The average annual rainfall ranges between 900 and 920 mm, and the main rainy season in the woreda is from mid-April to October (Abobo Woreda Office of Finance and Economic Development (AWOFED), 2023).

According to Central Statistical Agency (2007), the total population of the district is 15,741. In Abobo, there is crop production with gradual encroachment to rangelands showing the future expansion of crop cultivation. Farmers rear cattle, goats and chickens together with their crop cultivation practices. They produce cereal crops mainly maize, sorghum, sesame, millet, and rice. In Abobo woreda, there are two major types of farming systems: mixed farming and shifting cultivation practiced by settlers and native local people of the area, respectively (Gelayenew et al., 2016).

Out of the total farm area of 535 km^2, about 355 km^2 is under the control of small-scale farmland holders and the remaining 180 km2 land is in the hands of large-scale farmholders. The populations of interest for this research were maize-growing household farmers, especially the HHs that grew maize in the 2023/2024 cropping season.

2.2 Sampling technique and sample size determination

In this study, a two-stage random sampling technique was used to select sample households. In the first stage, out of the 16 maize producers, kebeles existed in the district; four kebeles (mender 7, 8, 11/12 and 13, Table 1) were randomly selected. In the second stage, 152 sample farmers were selected using a simple random sampling

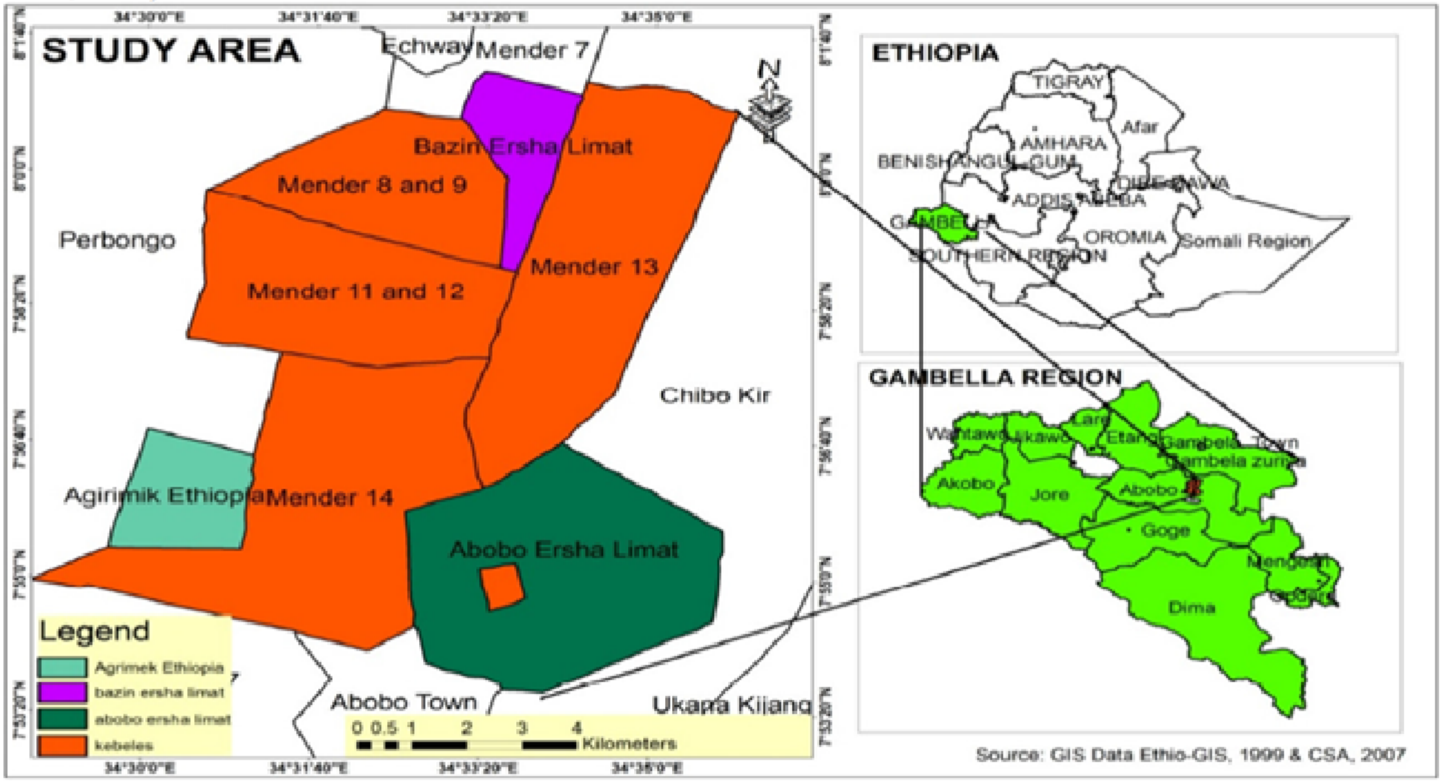

Figure 1: Map of the study area

technique based on the probability proportional to the size of the maize producers in each of the four selected kebeles. The sample size was determined based on the following formula given by (Yamane, 1967):

The formula used for the sample size determination is

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

$$n = \frac{1100}{1 + 1100(0.08)^2} = 152$$

2.3 Data types and methods of data collection

This study used both qualitative and quantitative types of data. Both primary and secondary data sources were used. The primary data was collected from sample households using a structured questionnaire that was administered by the trained enumerators based on the actual farming practices existed in the study area. Moreover, the local measurement scales customarily used by the farmers were converted into their respective standard units to minimize the measurement errors that could arise from the variability of the local units. Secondary data were collected from local administration offices, governmental and NGOs, published and unpublished documents and CSA, which were used as additional information to strengthen the primary information provided by the sample households in the study area. FGD and key informant interviews were conducted with farmers, development agents, concerned agricultural professionals and administration offices at all levels by the researcher.

2.4 Methods of data analysis

An econometric model such as the Cobb-Douglas stochastic production frontier model was used to predict the price efficiency scores of the sample farmers and the Tobit model was used to analyze the determinants of price efficiency.

2.4.1 Dual cost approach of efficiency measurement

According to Sharma et al. (1999), the dual cost frontier of the Cobb-Douglas production functional form is defined as follows:

$$\ln(C_i) = \beta_o + \sum_{j=1} \beta_j \ln P_{ji} + \beta_j Y^* \tag{2}$$

Given the input-oriented function, the efficient cost function can be specified as follows:

$$\min_{x} c = \sum_{j=1} W_j X_j \tag{3}$$

Table 1: Sample distribution of maize producer households in the selected kebeles

Selected Kebeles	Total number of households	Number of sampled households	Proportion of sampled households (%)
Mender 7	214	28	19.68
Mender 8	423	65	39.25
Mender 11/12	260	35	21.50
Mender 13	203	24	19.57
Total	1100	152	100

Source: Abobo District Agricultural Office and its own computation

Subjects to

$$Y * _{A} XjjWhere \quad Exp(_{0}) \quad A \tag{4}$$

The solution to the problem in the above equation is the basis for driving the dual cost frontier. Substituting the input demand equations derived using shepherd‘s lemma (4) and the yield adjusted for stochastic noise (predicted value of yield) in the minimization problem above, the dual cost function can be written as follows:

$$C(Y\, i*,\, W\,)HY\, ijWjj \tag{5}$$

According to **sharma1999**, the explained cost measures that enable us to estimate PE are:

$$CiC(Wi,\, Y\, i*,\,) \tag{6}$$

where i refers to the i_{th} sample household, Ci is the minimum cost of production, Wi denotes input prices; Y□ refers to farm output, which is adjusted for noise and □ ’ s is parameters to be estimated.

2.4.2 *Efficiency measurement*

Most empirical studies on efficiency in Ethiopia were analyzed using the Cobb-Douglas stochastic production frontier model (Asfaw et al., 2019; Nigusu, 2018; Tolesa et al., 2019). The main reason is that the stochastic production frontier model allows for statistical noise such as measurement error and climate change, which are beyond the control of the farmers. Following Aigner et al., 1977 , the specified stochastic production frontier (SPF) model was defined as follows:

$$\ln(Y_{i}) = F\,(X_i, \beta_i) + v_i - \mu_i \quad i = 1, 2, 3 \ldots n \tag{7}$$

Where: i- Indicates the number of sample households ln $(Y\,i)$- Indicates the natural log of the (scalar) output of the ith household. $F\,(X_i, \beta_i)$ ¬¬ is a convenient frontier production function (e.g., Cobb-Douglas); X_i- Represent a vector of input quantities used by the ith household β_i– Indicates a vector of unknown parameters to be estimated v_i- is a symmetric component and permits a random variation in output due to factors beyond the control of the decision-making unit, such as weather, measurement error, omitted variables, and other exogenous shocks. It is assumed to be independently and identically distributed $N\ (0,\ \sigma^2{}_v)$ and μ_i - intended to capture the inefficiency effects in the production of maize measured as the ratio of the observed output to the maximum feasible output of the i^{th} afarmer. It was assumed to be independently and identically distributed as a half-normal $u\ N\ (u,\ \sigma^2{}_u)$.

The dual cost function, which was derived analytically from the SPF, is given on the basis of the following for computing price efficiency:

$$\ln CM_i = 2.51 + 0.03 \ln w_{1i} + 0.32 \ln w_{2i} + 0.01 \ln w_{3i} + 0.17 \ln w_{4i} + 0.08 \ln w_{5i} + 0.02 \ln w_{6i} + 0.48 \ln Y * \tag{8}$$

where ln is the natural logarithm; CMi is the minimum cost of maize production of the ith farmer; w1i refers to the price of seed per kg; w2i is the cost of land per ha; w3i is the cost of NPS per kg; w4i is the cost of urea per kg; w5i is the cost of oxen per day; w6i is the cost of labor per day; Y□ is an index of output adjusted for any statistical noise and scale effects; ith refers to the ith sample household.

2.4.3 *Determinants of price efficiency*

In this study, to analyze the effect of demographic, socio-economic, farm attributes and institutional variables on price efficiencies, a second stage procedure was used where the efficiency scores estimated from the stochastic production frontier were regressed on the hypothesized explanatory variables using the Tobit model. This model is best suited for such analysis because of the nature of the dependent variable (efficiency scores), which takes values between 0 and 1 and yields the consistent estimates for the unknown parameter vector (Maddala, 1999). Estimation with the OLS regression of the efficiency score would lead to a biased parameter estimate since the OLS regression assumes a normal and homoscedastic distribution of the disturbance and the dependent variable (Greene, 2003). Following Maddala (1999), the model can be specified as

$$y^*_{i\,PE} = \delta_0 + \sum_{n=1}^{n} \delta_n Z_{in} + \mu_i \tag{9}$$

Where: i refers to the i^{th} farm in the sample households, n is the number of factors affecting price efficiency; y_i is efficiency scores representing the price efficiency of the i^{th} farm. y_i the latent variable, δ_n are unknown parameters to be estimated and μ_i is a random error term that is independently and normally distributed with a mean of zero and a common variance of σ^2 μ_i $IN(0, \sigma^2)$. Z_{in} are demographic, institutional, socio-economic, and farm-related variables that were expected to affect price efficiency. Denoting yi as the observed variables,

$$y_i = \begin{cases} 1 & if y^*_i \geq 1 \\ y^*_i & if 0 < y^*_i < 1 \\ 0 & if y^*_i \leq 1 \end{cases} \tag{10}$$

The distribution of the dependent variable in equation (10) is not a normal distribution because its value varies between 0 and 1. The ordinary least square (OLS) estimation will give biased estimates (Maddala, 1999). Therefore, the alternative approach is to use the maximum likelihood estimation (MLE), which can yield consistent estimates for unknown parameters. Following Maddala, 1999, the likelihood function of this model is given by

$$L(\beta, \delta \mid y_j, X_j, L_{1j}, L_{2j}) = \prod_{y_j = L_{1j}} \phi\left(\frac{L_{1j} - \beta' X_j}{\delta}\right) \times \prod_{y_j = y_j^*} \frac{1}{\delta}\varphi\left(\frac{y_j - \beta' X_j}{\delta}\right) \times \prod_{y_j = L_{2j}} \left(1 - \phi\left(\frac{L_{2j} - \beta' X_j}{\delta}\right)\right) \tag{11}$$

Where $L_{1j} = 0$ (lower limit) and $L_{2j} = 1$ (upper limit) where ϕ (.) and (.) are normal and standard density functions, respectively. In practice, since the log function is a monotonically increasing function, it is simpler to work with the log of the likelihood function rather than the likelihood function, and the maximum values of these two functions are the same (Greene, 2003).

The regression coefficients of the Tobit regression model cannot be interpreted like traditional regression coefficients that give the magnitude of the marginal effects of change in the explanatory variables on the expected value of the dependent variable. In a Tobit model, each marginal effect includes both the influence of the explanatory variables on the probability of the dependent variable to fall in the uncensored part of the distribution and on the expected value of the dependent variable conditional on it being larger than the lower bound. Thus, the total marginal effect considers that a change in the explanatory variable will have a simultaneous effect on the probability of being allocatively efficient and the value of the allocative efficiency score. A useful decomposition of marginal effects that was extended by Gould et al., 1989 was proposed by McDonald and Moffitt, 1980. From the likelihood function of this model stated in equation (6), Gould et al. (1989) showed the equations of the three marginal effects as follows:

The unconditional expected value of the dependent variable:

$$\frac{\partial E(y)}{\partial x_j} = \left[\phi(Z_U) - \phi(Z_L)\right] \cdot \frac{\partial E(y^*)}{\partial x_j} + \frac{\partial[\phi(Z_U) - \phi(Z_L)]}{\partial x_j} + \frac{\partial[1 - \phi(Z_U)]}{\partial x_j} \tag{12}$$

The expected value of the dependent variable conditional upon being between the limits

$$\frac{\partial E(y^*)}{\partial x_j} = \beta_n \cdot \left[1 + \frac{\{\Phi(Z_L) - \Phi(Z_U)\}}{\{\phi(Z_U) - \phi(Z_L)\}} - \frac{\{\Phi(Z_L) - \Phi(Z_U)\}^2}{\{\phi(Z_U) - \phi(Z_L)\}^2}\right] \tag{13}$$

The probability of being between the limits

$$\frac{\partial[\phi(Z_U) - \phi(Z_L)]}{\partial x_j} = \frac{\beta_n}{\sigma} \cdot \left[Z_L - Z_U\right] \tag{14}$$

Where $\phi(\cdot)$ is the cumulative normal distribution, $\varphi(\cdot)$ is the normal density function, $Z_L = -\beta' X/\sigma$ and $Z_U = (1 - \beta' X)/\sigma$ are standardized variables that come from the likelihood function given the limits of y^*, and σ is the standard deviation of the model. The marginal effects represented by the equations above were calculated by the STATA command mfx, which was complemented by specific options that allowed the estimation of the marginal effects of change in the explanatory variables.

The ratio of the standard error of $u(u)$ to the standard error v (v) known as lambda (), was 2.3802. Based on the value of the lambda, the gamma value is derived using the formula

$$\gamma = \lambda^2/(1 + \lambda^2) \tag{15}$$

3 Results and discussion

3.1 Demographic and socio-economic features

Age is one of the most important factors that determine the management experience of the farmers. The average age of the sample households during the survey period was about 42.24 years. This means that most household heads were within their productive age (Table 1).

Table 2: Descriptive statistics for the continuous variables

Variable description	Mean	Std. Dev.	Min	Max
Age (Year)	42.24	9.35	24	72
Education level (Year)	4.20	3.08	0	12
Family size (No.)	6.19	2.40	1	14
Total Cultivated land (ha)	1.48	0.87	0.25	4.75

Family labour plays an important role in the success of smallholder farming practices. In the study area, the average family size of the sampled households was found to be 6.22 with a minimum of 1 and a maximum of 14 (Table 1). Education is a tool to enhance the quality of labour and hence increase the efficiency of producers. According to the survey results, the average number of years of formal schooling of the sampled farmers was grade 4.20 (Table 1).

3.2 Farm and institutional characteristics

Land use and availability in the study area Land is a scarce resource and the most important factor of production for the rural people of the country in general and the study area in particular. The survey result shows that the mean land owned by the sampled farmers in the study area during the survey period was 1.78 ha. The mean cultivated land was 1.48 ha (Table 1).

Major crops grown in the study area

In the study area, the most important annual crops produced by the sampled households were maize; they produce root crops such as sweet potatoes and Taro/Godere' and fruit crops such as bananas, mangos and papayas (Tilahun et al., 2023). On average, sample households allocated 0.81 ha (57.86%) of the total cultivated land for maize production. Next, sweet potatoes and bananas were from roots and fruit crops that took the largest proportion of the household's total cultivated land covering 0.32 ha and 0.13 ha, respectively. The sample households allocated 0.11 ha and 0.06 ha of the total cultivated land for mangoes and papayas, respectively. Moreover, taro/Godere was a root crop that took a certain share of the household's total cultivated land covering 0.02 ha in the study area (Table 2).

Table 3: Average production of the major crops

Crop types	N	Production (Qt)		Area allocated (ha)	
		Mean	Percentage	Mean	Percentage
Maize	152	23.25	54.24	0.81	57.86
Sweet potatoes	112	7.21	16.81	0.32	20.12
Bananas	88	4.26	9.93	0.13	8.18
Mangos	64	3.57	8.31	0.11	6.92
Papayas	36	2.41	5.61	0.06	3.77
Taro/Godere'	22	0.95	2.21	0.02	1.26

The average production of major crops in quintals in the study area. Given the difference in productivity among crops, sample households on average got 23.25 quintals of maize, which is 54.21% of the total production (Table 2).

Major problems of maize production in the study area

their farming activities. From the problems, weed infection, shortage of fertilizer, shortage of improved seed, labor shortage, soil factors, maize disease, poor land preparation, and seed productivity problems were the major ones. Because of the study shows, soil factors were the main serious problem that farmers were facing followed by maize disease and fertilizer shortage. From the total sample, about 19.74% of respondents reported that they were facing soil factors, while 17.76% were facing maize disease and 13.81% of the farmers were facing fertilizer shortage. In addition, according to information obtained from the sampled respondents, there is a recently occurring disease that affects the yield of their maize crop. As they reported, it needs immediate control. Additionally, 13.16% and 12.50% of the respondents faced seed productivity problems and weed infection, respectively (Table 3). Farmers also reported an improved seed shortage during the peak agricultural production seasons.

Table 4: Major problems of maize production

Variables	Frequency	Percentage
Weed infection	19	12.50
Shortage of fertilizer	21	13.81
Shortage of the improved seed	15	9.87
Labor shortage	11	7.24
Soil factors	30	19.74
Maize disease	27	17.76
Poor land preparation	9	5.92
Seed productivity problem	20	13.16
Total	**152**	**100.00**

3.3 Econometric Model Outputs

3.3.1 *Production costs*

Like the production function, the mean and standard deviation of each variable used in the cost function along with their contribution to the total cost of production are presented in Table 4. On average, a total cost of 9197.11 birr was required to produce 23.25 quintal of maize. Among the various factors of production, the cost of labor and land accounted for the highest share of 2808.55 birr and 2421.88 birr, respectively. Following the cost of labor and land, the cost of urea, oxen, and NPS takes 1380.62 birr, 1320.32 birr, and 866.19 birr, respectively, out of the total cost of production. Among the total input used to produce maize output, the cost of seed took the smallest share, 380.15 birr (Table 4).

Table 5: Average maize production and its associated costs

Variable	Unit	Mean	Std. Dev.	Min	Max
Output	Quintal	23.25	14.67	5	72
Total cost of production	The birr	9197.11	6201.91	610	35410
Cost seed	The birr	380.15	226.32	99.92	1471.2
Cost land	The birr	2421.88	1438.79	700	7510
Cost NPS	The birr	866.19	553.55	190.3	3015
Cost urea	The birr	1380.62	898.13	262.75	4432
Cost oxen	The birr	1320.32	726.45	360	3440
Cost of human labour	The birr	2808.55	1517.92	634	7830

3.3.2 Maximum Likelihood Estimation and Stochastic Production Frontier

Using Maximum Likelihood Estimation (MLE) of the parameters (equation 11) and the Stochastic Production Frontier (SPF) (equation 7) were obtained using the Stata 13 computer program. The results of the ML estimates of the average production function are presented in Table 5. The result of the model showed that, from the total of six variables considered in the production function, four inputs (land, seed, oxen, and labor) had a significant effect in explaining the variation in maize yield among the sampled farmers. The coefficients of the production function are interpreted as the elasticity of the output produced with respect to the input used. If there is a 1% increase in land, amount of seed, number of oxen and amount of labor allotted for maize production, maize output would increase by 0.3190%, 0.2827%, 0.1244% and 0.1574%, respectively, suggesting that maize production was responsive to land, seed, oxen and labor in the study area. This result agrees with the findings of Meftu, 2016; Mustefa et al., 2017; Sisay et al., 2015 . Hence, the increase in these inputs would increase the production of maize significantly as expected. Moreover, the coefficient for land used was 0.3190, which implies that, at meters paribus, a 1% increase in land would result in a 0.3190% increase in maize production. Alternatively, this indicates that maize production was more responsive to land.

Table 6: Estimation of the Cobb-Douglas frontier production function

Variables	MLE Parameters	Coefficient	Std. Err.
Constant	β_0	1.1751**	0.5064
LNSEED	β_1	0.2827***	0.0945
LNLAND	β_2	0.3190***	0.1031
LNPS	β_3	0.0615	0.0704
LNUREA	β_4	0.0900	0.0690
LNOXN	β_5	0.1244*	0.0609
LNLBR	β_6	0.1574*	0.0800
Variance Parameters			
$\sigma^2 = \sigma_v^2 + \sigma_u^2$		0.2306***	0.0512
$\lambda = \sigma_u/\sigma_v$		2.3802***	0.1130
Gamma (γ)		0.850	
Log likelihood		-40.97	
Return to the scale		1.035	

Note: *, ** and *** refer to the 10%, 5% and 1% significance level, respectively.

Return to the scale of all input used in the production process is the measure of the total factor in productivity. The scale coefficient was calculated to be 1.035, indicating increasing returns to scale (Table 5). This implies that there is potential for maize producers to continue to expand their production because they are in stage I of the production surface, where resource use and production are believed to be inefficient. Therefore, a percent increase in all inputs proportionally would increase the total production by 1.035%. This is consistent with the findings of Mustefa, 2014; Solomon, 2012; Tolesa et al., 2019 , who estimated the returns to scale to be 1.0404%, 1.039% and 1.0341% respectively in their studies, which falls in stage I of production surface. The diagnostic statistics of the inefficiency component revealed that sigma squared (⍰2) 0.2306 was statistically significant at 1%. This indicates the goodness of fit, and the correctness of the distributional form assumed for the composite error term.

Based on gamma value estimate, it was shown that about 85% of the variations in the output of maize was caused by technical inefficiency. The remaining 15% variation was due to random noise that was beyond the control of the smallholder farmers.

3.3.3 Efficiency score of maize producers in the study area

The mean level of price efficiency of farmers in the study area was 70.9% and ranged from 35.03% to 91.80%, indicating that on average, maize producer households can save 29.1% of their current cost of inputs if resources are efficiently utilized (Table 6). This shows that there is an enormous opportunity to increase the efficiency of maize-producing households by reallocating resources in a cost-minimizing way. For instance, a farmer with an average level of price efficiency would enjoy a cost saving of about 22.77% derived from (1 – 0.709/1.000)*100 to attain the level of the most efficient farmer. The most price-inefficient farmer would have an efficiency gain of 61.84% derived from $\frac{10.3503}{1.000} \times 100$ to attain the level of the most price-efficient household. This result is close to the results of Tukela et al. (2013), Alelign (2017) and Tolesa et al. (2019).

Table 7: Summary statistics of the efficiency score of the sample households

Variable	Observation	Mean	Std. Deviation	Minimum	Maximum
PE	152	0.709	0.110	0.350	91.80

3.3.4 Distribution of the price efficiency scores

The price efficiency distribution score shows that 38.82% of the sample households had a price efficiency score between 70 and 79.99%. Households in this group can save at least 20% of their current cost of inputs by behaving in a cost-minimizing manner. About 25.66% of the maize farmers in the study area were operating between the efficiency score of 60 to 69.99% (Fig. 2). Only 1.32% of the total sample households had a price efficiency score above 90%.

This shows that almost all maize-producing households (98.68%) can at least save 10% of their current input cost by reallocating resources in a cost-minimizing way.

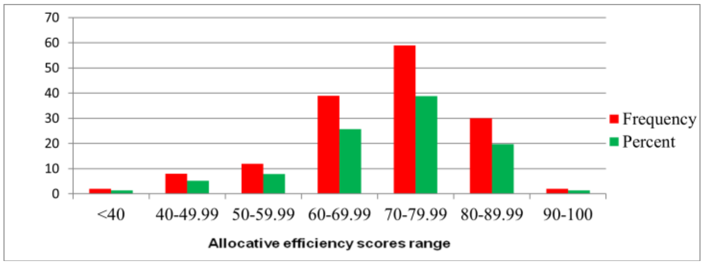

Figure 2: Distribution of price efficiency scores (%)

3.3.5 *Determinants of the price efficiency of maize-producing farmers*

The results of the Tobit regression model showed that among the hypothesized variables, three variables (livestock holding, frequency of extension contact and land fragmentation) significantly influence the price efficiency of smallholder farmers in maize production in the study area.

Livestock holding: The coefficient for livestock holding (TLU) was positive and had a significant influence on PE at the 10% significance level. The result reveals that having the largest number of livestock holdings helps to shift the cash constraint, provide manure and satisfy all the needs of farmers in the study area. Each unit increase in the value of TLU would increase the probability of a farmer being price efficient by 0.238% and the expected value of PE by about 0.398% with an overall increase in the probability and the level of PE by 0.442%. This finding was consistent with the results obtained by Getachew et al., 2017; Kifle et al., 2017; Mustefa, 2014; Saulos, 2015; Solomon, 2012.

Frequency of extension contact: Unfortunately, the frequency of extension contact affects price efficiencies significantly and negatively at a 10% significance level. This might be due to the fact that as a farmer contacted the extension worker frequently, he/she would not have enough time to potentially and appropriately allocate the resources. They are trained to maximize the output of the farmers to solve the problem of food security, and they have limited knowledge for appropriate resource allocation. In addition, during data collection, farmers in the area said that most of the time extension workers did not raise issues specific to agricultural production mechanisms (agronomic practices, post-harvest handling, crop disease control methods, etc.) rather they spent more time in involving on the activities which are not related to their professions or non-farm activities. For instance, health-related issues (construction of toilets, initiating farmers to vaccinate their children, etc.), awareness creation on political issues and collection of loans and taxes. So, there is no new knowledge they got from extension workers regarding agricultural production in order to improve their skills. Generally, these factors would make the efficiency of the farmers to decline. Furthermore, the computed marginal effect indicated that a unit increase in the number of extension contacts would decrease the probability of a farmer being price efficient by 0.094% and the mean value of price efficiency by about 0.156% with an overall decrease in the probability and the level of price efficiency by 0.174%. This result is in line with the previous findings of Ermiyas, 2013; Fetagn et al., 2017; Jema, 2008; Musa H., 2013; Mustefa et al., 2017; Mustefa, 2014 .

The coefficient of land fragmentation for price efficiency is negative and statistically significant at the 10% significance level, as expected. The result confirms the expectation because fragmented land leads to reduced efficiency by creating a lack of family labor, wastage of time and other resources that would have been available at the same time. Moreover, as the number of plots operated by the farmer increases, it may be difficult to manage those plots. Moreover, the computed marginal effect indicated that a unit increase in the number of the plot would decrease the probability of the farmer being price efficient by 0.084% and the mean value of price efficiency by about 0.141% with an overall decrease in the probability and the level of price efficiency by 0.157%. This result agrees with the empirical results of Assefa et al., 2016; Mustefa et al., 2017.

4 Conclusions and recommendations

4.1 Conclusions

By and large, the agricultural sector in Ethiopia is characterized by its poor performance and subsistence orientation. While maize farmers are producing more than ever before, the demand for grain has consistently outpaced the supply. This requires looking for a means to increase the agricultural productivity of smallholder farmers. In this context, the measurement of the existing efficiency in agricultural production and identifying the determinant to seek alternative solutions for these problems becomes paramount. The result of the study shows that, on average, 23.25 quintal of maize was produced at a total cost of 9197.11 birr. Among the factors of production, the cost of labor and land accounted for the highest share, valued 2808.55 birr and 2421.88 birr, respectively. Among the total input used to produce maize output, the cost of seed took the smallest share, which accounted for 380.15 birr. The estimated mean values of the price efficiency levels were 70.9%. Accordingly, as expected, livestock holding had a positive and significant effect on price efficiencies, implying that household heads that had more livestock were more price efficient than the others. Furthermore, the frequency of extension contacts and land fragmentation have negative and significant impact on price efficiency. In all, the present study revealed that maize producers in the study area are not operating at full levels of agricultural efficiency (AE), and there exists considerable room to improve the levels of AE of maize producers in the study area.

Table 8: Tobit model estimates for the determinant of PE and its marginal effects

Variable	PE		Marginal effects (PE)		
	Coefficient	Std. Err	$\frac{\partial E(y)}{\partial x_j}$	$\frac{\partial E(y*)}{\partial x_j}$	$\frac{\partial[\Phi(Z_U) - \Phi(Z_L)]}{\partial x_j}$
Constant	0.8385***	0.06723	0.00896	0.00759	0.00752
LIVESTSIZ	0.0045*	0.00269	0.00442	0.00398	0.00238
EXTENCNT	-0.0017*	0.00095	-0.00174	-0.00156	-0.00094
LNDFRGMNT	-0.0016*	0.00082	-0.00157	-0.00141	-0.00084

Note: *, ** and *** significant at the 10%, 5% and 1% level of significance, respectively.
$\frac{\partial E(y)}{\partial x_j}$ (Total change), $\frac{\partial E(y^*)}{\partial x_j}$ (Expected change) and $\frac{\partial[\Phi(Z_U) - \Phi(Z_L)]}{\partial x_j}$ (change in probability).

4.2 Recommendations

The results of this study provide information to policy makers on how to minimize the cost of production and improve the efficiencies of farmers in the study area. The following policy recommendations were drawn based on the results of the study.

- Use efficient farmers as benchmarks to set targets, identify weaknesses, and share knowledge through field days, visits, forums, and training.
- Improve livestock production by addressing feed shortages and health services to boost efficiency
- Strengthen extension agents' focus on input allocation, cost minimization, and skill upgrading with better policy support.
- Consolidate fragmented farms and expand household farm sizes through resettlement or off-farm opportunities.
- Go beyond technical efficiency by examining allocative and economic efficiencies to enhance crop performance over time.

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Data Availability

' Data can be made available on the behavior of the request

Declaration of interests' statement

The author declares no competing interests.

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