

Analysis of Technical, Allocative And Economic Efficiency In Maize Production In Ethiopia Evidence From Low Land of Gudeya Bila : Stochastic Frontier Approach

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Research

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Posted Date: August 18th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-792476/v1>

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Analysis of technical, allocative and economic efficiency in maize production in Ethiopia
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Abstract

Traditionally farming system of rural area in Ethiopia is based on producing maize without oxen ploughing which is characterized with clearing land by their own land and cultivating it without oxen ploughing. Thus for many years the farmers of Ethiopia are unable to meet their food security. This situation is continued currently in the study area in which the production system of maize is based on producing advanced methods of production that need improvements of efficiency of farmers. Therefore these studies analyze economic efficiency and constraints of maize production under shifting in the low land farming of Gudeya Bila district. The study was conducted using cross-sectional data collected during the 2020/2021 production year from 154 randomly selected sample households. To estimate the level of technical, allocative and economic stochastic production frontier model was employed and Tobit model was used to identify factors affecting technical, allocative and economic efficiency of sample households. The mean technical, allocative and economic efficiency were 78.78%, 69.99% and 56.66% respectively. The Tobit model results shows that education levels, family size, farm size, construction of terrace, frequency of extension contact, uses of credit, participation in off/non-farm activities and shifting cultivation had a significant positive effect on technical efficiency. Livestock holding and participation in off/nonfarm activities have positive effects and distance to plot were found to have negative effect on allocative efficiency while family size, soil conservation practice, credit, extension service, off/non-farm activities were found to have positive effect and distance to plot is negative influence on economic efficiency. The main conclusion steaming from this analysis was there is the possibility to enhance the efficiency of maize producers in the study area. Thus policies and strategies of the government should be directed towards the contraction of terrace, shifting from shifting cultivation to oxen farming, producing by fragmented of land rather than focusing only on single plot.

Key words: Cobb-Douglas, Efficiency, Smallholders farmers, stochastic frontier and Tobit

1. Introduction

Agriculture in Ethiopia was prevailing in bringing down poverty. Nevertheless; vulnerability of returning to poverty remains high, particularly for rural livelihoods dependent on rained agriculture (World Bank, 2016). More ever agriculture in most developing countries is stagnant due to inefficiency in farm production that was not able to meet available food demand (Abdul, 2013). Similar to most developing countries Ethiopia is one of the struggler in terms of agricultural production efficiency in the face of ever rising population growth rate that is unable to fulfill the need of local community(Nandeeswara and Bealutukela, 2015).Farming techniques have changed little over the centuries yielding low outputs and making farmers vulnerable to the effects of unpredictable weather patterns (ATA, 2016;Tefaye and Beshir, 2014).The Ethiopian government initiated new extension programs which had given the main concern to maize over long periods of time for the reason that its known ability to respond positively to improved inputs and the opportunity of achieving dramatic growth in productivity (Samuel, 2006).Even if maize is an important food crop and the efforts made so far to generate and disseminate improved technologies, its productivity remains below its potential. Increment of productivity and production of agricultural sector by using improved technologies can be high if there is improvement of the existing level of efficiency of farmers (Asefa, 2011).Moreover it is not sufficient to meet national requirement of production by only yield-enhancing agricultural technologies in the country (Tura *et al.*, 2010 ;Sorsie *et al.*, 2015 and Kitila and Alemu, 2014).Consequently if farmers are producing to supply the surplus to the market after feeding themselves with reducing land per capita due to population growth, they need to adopt new farming practices and increase their efficiency (Jema, 2008;Geta *et al.*, 2013 and Alelign, 2017).Thus is study intended to feel the gap in the study area by analyzing the levels of small holder farmers economic efficiency and by identifying the factors affecting economic efficiency of smallholder farmer's in the study area.

2. Research Methodology

Description of the Study Area

This study was carried out in low lands of Gudeya Bila district, which is one of the 17 districts located in the northeastern part of East Wollega zone. The district has a total estimated population of 71629 of whom 49.2% are men and 50.8% are women; and 86.85% of its population is rural dwellers. The farming system in the district is mainly mixed crop-livestock production. Most farmers in the district undertake both crop production and livestock rearing activities. Agriculture is mainly characterized by rain-fed production system. Maize is one of the major cereals grown in the low lands of the district in which farming is mostly with limited oxen.

Sampling techniques and Sample size determination

Two stage random sampling techniques was used for this the study to select sample respondent. In the first stage three Kebeles of namely Zangi, Gute Chancho and Abay Dale were purposively selected from the district since they are low land of the district and maize is the dominant crop grown in the study area. In the second stage 60, 24 and 70 sample household was selected by simple random sampling from three kebeles. Finally 154 households that produce maize were selected by probability proportional to sample size. The households were selected for survey and sample size was determined based on the formula given by Yemane (1967).

Sources and method of data

Primary data was collected through cross-sectional survey from 154 households with information collected at household level in low land of the district. Also Secondary data was collected from different journal, internet, published research, and bureau of agriculture of the district. The research will adopt cross-sectional survey as in opposition to time series/panel data primarily due to lack of repeated measurement, cost and time implications. Cross-sectional survey enables to collect data at a point in time; it is cost-effective and time saving (Kothari, 2004). This research employed cross-sectional survey using structured questionnaire,

field observation and focus group discussions in the low land area. Structured questionnaire was used to generate information at household level. The data to be collected include household level output of maize in low land area, the inputs used in the production process and the socioeconomic, demographic, institutional and farm-specific characteristics, input price, cost of input incurred during maize production period such as amount and cost of labour used, rental cost of land, cost of oxen used, and cost seed and fertilizer.

Specification of Model for efficiency and determinants of efficiency in the low land of the study area

Following Aigner *et al.* (1977) and Meeusen and van Den Broeck (1977), the stochastic frontier model model is defined as:

$$Y_i = f(X_i; \beta) + v_i - u_i \tag{1}$$

Where Y_i measures the quantity of maize output of the i^{th} farm in low lands of the district, X_i is the vectors of explanatory variables used by the farmer i^{th} in the low land such as land, labor, urea fertilizer, NPS fertilizer, oxen and seed used by sample household.

The β is the vector of unknown parameters. The functional specification $f(X_i; \beta)$ is a suitable production function (Cobb-Douglas). The disturbance term v_i is intended to capture the effects of the stochastic noise and it is assumed to be $v_i \sim N(0, \delta^2)$. The disturbance, u_i , captures the technical inefficiencies.

According to Sharma *et al.* (1999), the above cost measures are used to estimate the technical, allocative and economic efficiencies respectively. We can define the farm-specific technical efficiency in terms of observed output (Y_i) of low land maize to the corresponding frontier output (Y_i^*) using the existing technology.

$$TE_i = \frac{Y_i}{Y^*} \tag{2}$$

The farm specific economic efficiency is defined as the ratio of minimum observed total Production cost (C^*) to actual total production cost (C).

$$EE_i = \frac{C^*}{C} \tag{3}$$

Following Farrell (1957), the allocative efficiency index can be derived from Equations (1) and (2) as Follows:

$$AE = \frac{EE}{TE} \tag{4}$$

After estimating the level of technical, allocative and economic efficiency from Stochastic production frontier they were regressed using a censored Tobit model on farm specific explanatory variables that was explain variation in efficiency across farms. As the distribution of the estimated efficiencies is censored from above at the value one, Tobit regression (Gujarati, 2004) is specified as:

$$E^* = \delta_0 + \delta_m Z_{im} + \mu \tag{5}$$

$$v/z \approx normal(0, \delta^2)$$

Where E^* – latent variable representing the efficiency scores of farm j,

δ – a vector of unknown parameter to be estimated

Z_{im} – a vectors of explanatory variables m(m=1,2,...n)for farm household

X1=Age of household in year

X2=Sex which is either male or female

X3=Education levels in year of schooling

X4=wild animals consumption of maize (1 if consumed and 0 if not consumed)

X5=Farm size in hectare

X6=Livestock in tropical livestock unit

X7=Fertility which is either fertile or infertile

X8=Shifting cultivation which is either farmers cultivate under shifting or with oxen

X9=Terrace which is either cultivated land is contracted by terrace or not

X10=Land fragmentation which is one for one plot zero otherwise

X11=Extension measured by frequency of extension contact

X12=Credit which is dummy variables whether farmers receives credit from microfinance institutions such as oromia credit and saving share company and wasasa or not

X13=Off/non-farm which refers to whether farmers engaged in off/non-farm activities such as handcrafting, petty trading, service renting and resource extraction or not

μ – Error term that is independently and normally distributed with zero mean and variance δ^2

Denoting E_i as observed variables,

$$E_i = \begin{cases} 1 & \text{if } E_i^* \geq 1 \\ 0 & \text{if } E_i^* \leq 0 \end{cases}$$

6

3. Results and discussion

Maize Production constraints

Effect of wild animals such as monkey and ape are common the low land of the district since it is the major problem that farmers were facing in the study area which is the 25.32 percent .In the low land about 16.25 percent of respondents reported soil factor was the problem that they were facing. In addition to this 12.99 percent of the respondent faces poor seed productivity problem in the study area. Farmers also reported that there was labour shortage during peak agricultural production season (Table1)

Table 1.Maize production constraint under shifting cultivation farming system in low land of the study area

Variables	Frequency	Percent
Problem due to wild animal	39	25.32
Seed productivity problem	20	12.99
Weed infestation	13	8.44
Poor land preparation	22	14.29
Shortage of oxen	10	6.49
Labor constraint	14	9.09
Shortage of land	11	7.14
Soil erosion	25	16.23
Total	154	100.0

Source: descriptive statics result

Descriptive statistics of production function variables

On average, sample farmers obtained 28 quintal of maize. On average the cultivated land area allocated to maize production (both owned and shared land that may be shared in and shared out) by household was 0.70 hectare and ranged from 0.2 hectare to 3 hectare with a standard deviation of 0.4. The amount of seed that sampled households used were 21.5 kilogram on average. Like other inputs, human and animal labor inputs were also important, given a traditional farming system in the study area. Sampled households, on average, used 80.75 man equivalent labor and 21.6 oxen days for the production of maize during 2020/2021 production season (Table 2).

Table 2.summary of production function variables

Variables	Measurement unit	Mean	Standard deviation	Minimum	maximum
Output of maize in lowland	Quintal	23.05	14.63	2	90
Local seed maize	Kilogram	21.5	11.6	3	70
Land allocated for maize	Hectare	0.80	0.4	0.2	3
Nitrogen phosphorus sulfur	Kilogram	76.45	46.7	13	300
Oxen used	Oxen day	21.6	10.8	0	68
Labor used	Man day	80.75	37.47	18.6	305

Source: Descriptive statics result

From the total of five variables considered in the production function, three variables (seed, land and labor) had a significant effect in explaining the variation in maize yield among farmers. The coefficients of the production function are interpreted as elasticity. Hence, elasticity of output to land, seed and labor are 0.34, 0.29, 0.18 respectively suggests that maize production was more sensitive to land. As a result, 1% increase in amount of land will result in 0.34% increase in maize production, keeping other factors constant The scale coefficient was calculated to be 1.13 indicating increasing returns to scale (Table 2).This implies that there is potential for maize producers to continue to expand their production because they are in the stage I of the production surface, where resource use and production is believed to be inefficient. This is in line with finding of Abdulai *et al.* (2013) found that maize production in northern Ghana exhibit increasing return to scale.

The dual cost function derived analytically from the stochastic production function is given as follows basis for computing allocative and economic efficiency

$$lCmi = 5.8 + 0.008\omega_1 + 0.45\omega_2 + 0.0078\omega_3 + 0.19\omega_4 + 0.07\omega_5 + 0.08\omega_6 + 0.99Y^* \quad 7$$

Where $lCmi$ is cost of producing maize; ω_1 refers to the price of seed, ω_2 is cost of land; ω_3 is cost of NPS; ω_4 is cost of UREA; ω_5 is cost of oxen; ω_6 is cost of labor Y^* is output adjusted for any statistical noise; i^{th} refers to the i^{th} sample household.

Estimation of production and cost functions

Table 3. Estimation of the Cobb-Douglas frontier production function

Variables	Ordinary least square		Maximum likelihood estimation	
	Coefficients	Std. Err	Coefficients	Std. Err
Constant	0.1011	0.4823	1.0135*	325
Lan seed	0.3351***	0.1025	0.34***	0.089
Lan Land	0.1940*	0.1026	0.29***	0.10
Lan NPS	0.0729	0.0818	0.08	0.0706
LNurea	0.1375*	0.0762	0.08	0.088
Lan oxen	0.1301	0.0950	0.16	0.0760
Lan labor	0.1776*	0.0939	0.18*	0.0900
R ²	0.7213			
F statistics	63.42			
$\delta^2 = \delta_v^2 + \delta_u^2$			0.23***	0.0526
$\lambda = \delta_u / \delta_v$			2.5395***	
Gamma (γ)			86.57	
Log likelihood			-44.01	
Sample size			154	

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

Source: model result (2021)

Technical, allocative and economic efficiency score

The result of frontier model revealed that, farmers in the study area were relatively good in technical efficiency than in allocative efficiency and economic efficiency of maize production in low land of the district. The mean technical efficiency level was 78.88% varies from 40.76 to 98.99 shows that maize producing farmers have an opportunity to efficiently utilize

resources and hence they could increase the current maize output by 21.12% using the existing technology. This shows that there is a wide difference among maize producer in their level of technical efficiency. The means allocative efficiency of farmers in the study area was 69.99 % and ranges from 36.76% to 97.6% indicating that on average, maize producer farmers can save 30.01% of their current cost of inputs if resources are efficiently utilized. This shows that there is enormous opportunity to increase the efficiency of maize producers by reallocation of resources in cost minimizing way. As illustrated in the above table 4. The mean economic efficiency level of sample households was 56.66 % with minimum and maximum efficiency scores of 19.9% and 94.8% respectively. That is the producer with an average economic efficiency level could reduce current average cost of production by 50.11% to achieve the potential minimum cost level without reducing output levels (Table 4). Technical efficiency result obtained from this analysis is below the finding of (Kifle, 2017). And above result of (Gosa and Jema, 2016). While allocative and economic efficiency result is below finding of and above finding of (Kifle, 2017).

Table 4. Summary statistics of efficiency score of sample households

Variables	Observation	Mean	Std.deviation	Min	max
Technical efficiency	154	78.78	0.1371	40.76	98.99
Allocative efficiency	154	69.99	0.1697	36.76	97.6
Economic efficiency	154	56.66	0.1807	19.7	94.8

Source: Stochastic model result (2021)

Determinants of efficiency in maize production in low land of district

As expected, the sign of education was positive effect on technical at 1% level of significance. This implying that more educated farmers are more technically efficient than those have relatively less education. This could be because more educated farmers were capable to identify, interpret and react to new information and adopt improved technologies such as improved seed, fertilizers, and planting materials much faster than their counterparts the result indicates education improves the acquisition and utilization of information on improved technology by the farmers. This result was in line with the findings of (Mustefa, 2017; Kitila

and Alemu, 2014).The coefficient of wild animals consumption of maize crop for technical efficiency and economic efficiency is negative and statistically significant at 10% and 5% percent significance level respectively. This implies that wild animals consume maize starting from planting to yield that decrease maize production efficiency in the study area. This variable is new variable of the study. The coefficient for livestock holding in Tropical livestock unit was positive and had a significant influence on allocative efficiency at 10% level. The result reveal that farmers having largest number of livestock holding helps to shifts cash constraint and to satisfy all needs of farmers in the study area. This finding was consistent with the result obtained by (Getachew, 2017; Kifle, 2017, Essa, 2011; Sorsie *et al.*, 2015; Tefaye and Beshir, 2014).The coefficient of farm size had positive relation with technical efficiency at 10% level of significance. It is measured as total land cultivated by the farmer including those owned and shared in the study area. In this study, it was hypothesized that farm size affects efficiency negatively. As the farm size of farm household increases, the managing ability of him/her will decrease given the level of technology, this lead to reduce the efficiency of the farmer. Unexpectedly, the estimated result not agrees with the expectation. This shows that a household operating on small area is less efficient than a household with large land holding size. This is mainly justified on the view that those farmers with large farm size can better diversify their crops and the better chance for maize to be planted on fertile soils. Additionally farmers with larger area of cultivated land have the capacity to use compatible technologies that could increase the efficiency of the farmer. As a result, with increase farm holding size the technical efficiency of the farmer might increase. This finding was in line with results obtained by (Rao and Bealu, 2015; Gosa & Jema, 2016; Wudineh & Endrias, 2016).

The shifting cultivation is negative and significant at 5% levels of significance on both allocative efficiency and economic efficiency. This relation may be because farmers shift their farm land may be fail to prepare their farm land on time and may faces management problem. Whereas, those farmers who cultivates without shifting cultivations are more efficiency since they may manage their farm land effectively. This implies that as the as farmers applies shifting cultivation on their farm land efficiency decrease. The coefficient of terrace on technical and economic efficiency was significant and positive at 1% and 10% respectively.

According to Jara-Rojas, *et al.* (2012), soil conservation practices not only increase production and productivity of farm land, but also enhances environmental sustainability. This result is in line with (Getahun 2014; Lemessa, *et al.*, 2017)

Table 5. Tobit model estimates for determinant of different efficiency

Variables	Technical efficiency		Allocative efficiency		Economic efficiency	
	Marginal effect	Standard error	Marginal effect	Standard error	Marginal effect	Standard error
Constant	0.4357***	0.0661	0.7053***	0.0643	0.3085***	0.0608
Age	0.0006	0.0012	-0.0011	0.00116	-0.0006	0.0011
Sex	-0.0138	0.0263	-0.0032	0.0256	-0.0039	0.0243
Education	0.0104***	0.0033	-0.0038	0.0032	0.0047	0.0031
Wild animal	0.0153*	0.0082	-0.0059	0.008	-0.0162**	0.0075
Farm size	-0.0237*	0.0133	-0.0003	0.0130	0.0156	0.0123
Livestock holding	-0.0042	0.0032	0.0058*	0.0031	0.0017	0.0030
Fertility	-0.0055	0.0213	0.0076	0.0207	0.0020	0.0196
Shifting cultivation	-0.0004	0.001	-0.0020**	0.0009	-0.0018**	0.0009
Terrace	0.0653***	0.0216	-0.0106	0.0210	0.0364*	0.0199
Land fragmentation	0.0065**	0.00118	0.0056	0.0056	0.0084	0.0053
Extension	0.0040***	0.0011	-0.0009	0.0011	0.0019*	0.0010
Credit uses	0.0584***	0.0222	0.0029	0.0216	0.0448**	0.0205
Off/non farm	0.0423*	0.0223	0.0437**	0.0217	0.0573***	0.0206
Loglikelihood	95.70		99.39		107.45	

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

Source: Tobit model results (2021)

As expected the coefficient extension was positive and significantly affected the level of technical, economic efficiencies at 1% and 10% level of significance respectively. Extension services are assumed to help in diffusion and adoption of new technologies. In addition this extension Services offer guidance to the farmers related to the use of various resources such as fertilizer and provide consultancy services in managing their scarce resources more efficiently. This result was in-line with (Mustefa, 2014; Hailemaraim, 2015; Musa, 2013).

The result also indicated that credit utilized had a positive sign and statistically significant effect on both technical efficiency and economic efficiency level at 1% and 5% level of significance. This suggests that on average households with credit utilized tend to exhibit higher levels of efficiency. This due to the reason that credit utilized allows a household to enhance efficiency by removing money constraints which may affect their ability to apply inputs, implements and farm management decisions on time. Hence use of credit reduces the problem of financial constraints, ensures timely supply and use of inputs and results in increased economic efficiency of the households in the study area. This finding is consistent with the result by (Beshir, 2016; Musa, 2013; Moges, 2017).

In this study the coefficient of off/non-farm activity was positive sign and statistically significant at 10%, 5%, 1% level of significance effect with respect to TE, AE, and EE respectively as expected. Off/non-farm activities may affect the efficiency positively for the reason that the income obtained from such activities could be used for the purchase of agricultural inputs, and supplement financing of household expenditures which would entirely dependent on agriculture and reduce cash constraint for timely purchase of agricultural input. In other word availability of off/non-farm income decreases cash constraint and enables households to make timely purchase of those inputs which they cannot provide from the farm income hence increases their efficiency. The result is in line with the findings of (Kifle 2017; Gizachew, 2018)

As expected the coefficient of land fragmentation is positive effect on technical efficiency in the low land of the district. This may be due to the reason that the farmers who cultivates in different

place survive from the animal effect such as monkey and apes which are affecting the product of maize before harvest.

4. Conclusion

The study results revealed that there is a considerable variability in all efficiencies and efficiency score of sample household in the production of maize in the study area since the production is characterized with shifting cultivation. The policy makers should give due emphasis to increase the level of efficiencies of the farmers who are far from the modern information and farming. This is because the use of improved technologies is expensive since farmers have serious financial problem because they are subsistence farmers. If their educational opportunities are improved the efficiency of the framers can be enhanced. Thus government should have designed appropriate policy to provide adequate and effective basic educational opportunities to the those low land population, both formal and non-formal education since those farmers are in remote area of the district there is less attention of the government on providing educational opportunities. Given the mixed farming system in the study area, farmers with more number of livestock were relatively better in the allocative efficiency. Hence, there is a need to design appropriate policy and strategies for improving livestock production systems by solving the shortage of feed which in turn will enhance the efficiency of maize production. Farmers who practice soil conservation practice is were relatively better in the technical and economic efficiency. Hence, there is a need to design appropriate policy and strategies for improving soil conservation practice systems by solving the soil fertility problem of maize production. Also to improve the land status by applying new soil conservation practices on their farm through improved sustainable land management practices especially terrace and soil bund is encouraged. other way may be providing practical attachment training with the current agricultural production and as much as possible decrease ratio of development agents to the number of farmers so as to increase the number of extension contact. This study provides evidence on the role of credit utilization in improving technical and economic efficiency positively through reducing financial limitations farmers face in purchasing inputs in maize production. Therefore, establishing adequate rural finance institutions and strengthening of the available micro-finance institutions to

assist farmers in terms of financial support through credit are crucial to improve farm productivity. In the study area since monkey and apes affects the product of maize providing controlling mechanism of those animals through tourism is very essential.

Declaration

Ethics approval and consent to participate: Not applicable

Consent for publication: I have agreed to publish this research work

Authors' contributions: Authors have collected data, analyzed interpreted and wrote the research

Competing interests: Author has no conflict of interest.

Availability of supporting data: No supporting data is available for this study

Funding: No fund is received

Acknowledgements: We gratefully acknowledge Wollega University

Authors' information: Authors' information (optional): Author was from Ethiopia. Author was graduate by Bachelor of Science in agricultural resource economics and management from Wollega University won the gold medal in 2015 and studied Msc in Agricultural economics from Jimma university. Currently served as lecturer in Wollega University for four year.

Acronomy: AE=Allocative Efficiency, EE= Economic Efficiency, TE= Technical Efficiency

TLU=tropical livestock unit

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