Economic Efficiency of Smallholder Farmers in Maize Production in Bako Tibe District, Ethiopia

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Abstract
Ethiopian agriculture is characterized by low productivity due to technical and socio-economic factors. To improve this problem integration of modern technologies with improved level of efficiency become more crucial. Accordingly, this study was conducted using Stochastic Frontier Production Function (SFPF) to estimate the level of Technical Efficiency (TE), Allocative Efficiency (AE) and Economic Efficiency (EE) as well as Tobit model to identify factors affecting these efficiencies. The mean of TE, AE and EE were 82.93%, 66.03% and 54%, respectively. The mean of TE and AE implies that there exists possibility to increase production by 17.07% without using extra inputs and decrease cost of inputs by 33.97%, respectively. The result revealed high inefficiency among maize producers. The Tobit model results revealed that age, off/non-farm activities, sex, amount of land owned and perception on agricultural policy had a significant effect on TE. Education, frequency of extension visit, perception on agricultural policy and livestock holding had significant effect on AE while age, off/non-farm activities, sex, land owned, credit utilized and perception on agricultural policy had a significant effect on EE. The result showed that there are opportunities to increase efficiency of maize production. Therefore, the policies and strategies in development and research may act on these variables to increase the efficiency level of maize producers.
Keywords: Cobb-Douglas, efficiency, maize, smallholders, stochastic frontier, Tobit

1. Introduction

Ethiopian agriculture is characterized by low productivity due to technical and socio-economic factors. Mostly the farmers with the same resources are producing different per hectare output, because of management inefficiency inputs, limited use of modern agricultural technologies, obsolete farming techniques, poor complementary services such as extension, credit, marketing, and infrastructure, poor and biased agricultural policies in developing countries like as Ethiopia (FAO and WFP, 2012; World Bank, 2007). To reverse the situation, the Ethiopian government has design Growth and Transformation Plan (GTP-I) in the five years (2011-2015). According to the plan, smallholder farmers are among the major targeted groups where increased agricultural productivity is believed to be achieved (David *et al*., 2011). One of the basic strategies of the Ethiopian government in improving agricultural productivity is to adopt new technologies and use of modern inputs.

Among the crops grown in Ethiopia, maize (Zea mays L.) is the most important cereal crop in terms of production, area coverage and better availability and utilization of new production technologies (Arega and Rashid, 2005). It is the first cultivated and highly demanded food crop in the study area as well as in the western part of Ethiopia.

Maize production can increase either through introduction of modern technologies or by improving the efficiency of inputs with existing technologies. These two are not mutually exclusive, because the introduction of modern technology could not bring the expected shift of production frontier, if the existing level of efficiency is low. This implies that the need for the integration of modern technologies with improved level of efficiency (Kinde, 2005). Therefore, a proper analysis of economic efficiency of farmers requires the estimation of both technical and allocative efficiencies.

The modeling and estimation of both technical and allocative efficiencies of agricultural production is often motivated by the need for a more complete representation of economic efficiency of farmers implied by the economic theory of production (Arega and Rashid, 2005). Though, while a considerable number of studies have dealt with technical efficiency of farmers in developing countries like Ethiopia, very few studies have analyzed both technical and allocative efficiencies (Sharma *et al*., 1999; Jema, 2008). To the best of our knowledge, there has been no study that analyses comprehensively the efficiency of inputs in the study area. Therefore, the present study is useful in formulating appropriate policies and research information for reducing level of economic inefficiency with objectives of to measure the level of technical, allocative and economic efficiencies in maize production of smallholder maize producers and to identify the determinants of technical, allocative and economic inefficiencies in maize production of smallholder maize producers in the study area.

2. Research Methodology

2.1. Description of the Study Area

BakoTibe district is located in West Shew zone of Oromia in the Western part of Ethiopia. It located at about 251 km from Addis Ababa, the capital city of Ethiopia. The average elevation of the district is 1610 masl and located 37.0575′ longitude and 09.015′ latitude. Geographically, it categorized into three agro-ecologies like lowland (51%), mid-highland (37%) and highland (12%) with annual rainfall and temperature range of 1200-1300mm and 13.8-27.8^{o}c, respectively.

The major crops grown around the area are cereal such as maize, sorghum, tef, wheat; pulse and oil like haricot, soybean, niger seed (noug) and horticultural crops such as pepper, mango, tomato, irish potato, sweet potato and sugarcane. Annual crops especially cereals are predominant and rain-fed agriculture is mainly practiced using animal power.

2.2. Data and Variables

Both primary and secondary data from different sources were used. The primary data were collected from sample households through face to face interviews during the 2013/2014 cropping season using a semi-structured questionnaire. Secondary data collected from Bureau of Agriculture, NGOs, Research Centers, CSA, etc and used as additional information to strengthen the primary information provided by the sample households for rational conclusion.

A combination of both purposive and multiple stage random sampling techniques were employed to draw an appropriate sample households. BakoTibe district was purposively selected due to the presence of large number of maize producing households and among the major maize growing district in the country. Three kebeles were selected randomly based on the extent of maize production trend. Finally, about 124 sample households were selected randomly using probability proportionality size following a simplified formula provided by Yamane (Yamane, 1967).

Accordingly, the required sample size at 95% confidence level with degree of variability of 5% and level of precision 9% are used to obtain a sample size required which represents a true population.

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

Where, n = sample size, N = Population size and e = level of precision considered (9%)

One output and seven input variables were used in estimating the parametric stochastic frontier function. The output variable is physical quantity of maize produced during 2013/2014 crop production year by a farm household and measured in quintal. Inputs data were collected on fortnightly basis by asking the farmer to recall his/her activities on that particular plot during the 2013/14 crop production year. Data labor is disaggregated by age and gender and converted into adult-equivalent. The quantities of land, seed, oxen, DAP, Urea, chemicals and prices of all purchased and rented inputs were collected during this time used for maize production.

Sixteen variables (AGE) age of households in years which can serve as proxy for experience, (EDUCLH) education level of household head in years and used as a proxy for managerial ability, (HHSZE) household size in number, (SEX) sex of household head, (OFNFA) participation in off/non-farm activities which can serve as additional income, (TCULTLND) total cultivated land (own, shared or rented in) land managed by household in hectare, (LNDOWNR) land ownership for maize production and households are given priority to their own plot, (CRDTU) credit utilized which is source of financing agricultural activities, (FREXTVST) frequency of extension visit in number and medium for the diffusion of new technologies among farmers, (TRAING) participation in training and tool in building managerial capacity of the smallholder farmers, (LNDFRAG) land fragmentation in number which means total plots used for maize production, (SLOPE) slope of plot, (PROXTY) proximity to maize plot in minute, (PAGRPOLY) perception on agricultural policy such as pricing, marketing and other public provisions, (PENVHZRD) perception on environmental hazard such as climate change and weather condition affected maize production and (TLU) livestock holding and support maize production (source of cash, draft power and manure) were included in Tobit model to identify factors affecting the inefficiency level of farmers.

2.3. Sampling Design and Methods of Data Analysis

For the investigation of the technical, allocative and economic efficiencies of maize production, separate SFPF of the following form were estimated

$$lnY_i = \beta_0 + \beta_1 \ln(land) + \beta_2 \ln(labor) + \beta_3 \ln(oxen) + \beta_4 \ln(Urea) + \beta_5 \ln(DAP) + + \beta_6 \ln(seed) + \beta_7 \ln(chemicals) + v_i - u_i \qquad (2)$$

Where: Y_i denoted total physical quantity of maize output of the ith farm (qt); *land* denotes the total land planted to maize in hectare; *labor* denotes the total family labor, exchange labor and hired labor used in man-days; *oxen* denotes the total own oxen, exchange oxen and hired oxen used in Oxen-days; *Urea* and *DAP* denotes quantity of chemical fertilizer used in kg; *seed* denotes the total quantity of seed used in kg and *chemicals* denotes quantity of chemicals (pesticides, insecticides, herbicides and fungicides) used for maize production (lit); β_i denotes vector of unknown parameters to be estimated; v_i denotes a disturbance term which accounts for factors outside the control of the farmer and u_i denotes non-negative random variable which captures the technical inefficiency in production.

The solution to the cost minimization problem is the basis for deriving the dual cost frontier, given the input price (ω_j), parameter estimates of the stochastic frontier production function ($\tilde{\beta}$) and adjusted output level Y_i^*.

$$\text{MinxC} = \sum_{j=1}^{7} X_j \omega_j \tag{3}$$

Subject to $Y_i^* = \hat{A} \prod X_j^{\tilde{\beta}_j}$

$Where, \hat{A} = Exp(\tilde{\beta}_0)$. Substitution of the cost minimizing input quantities into equation (3) yields the following dual cost function

$$C(Y_i^*, \omega; \alpha_j) = HY_i^{*\mu} \prod_j \omega_j^{\alpha_j} \tag{4}$$

$$\text{Where; } \alpha_j = \mu\tilde{\beta}_j, \mu = \left(\sum \tilde{\beta}_j^{-1}\right) \text{and } H = \frac{1}{\mu}\left(\hat{A} \prod \tilde{\beta}_j^{\beta_j}\right)^{-\mu}$$

All parameters are known and inputs prices (ω_j) are averages of observed prices per unit of the inputs used. Hence, we can calculate farmer-specific technical efficiency in terms of observed output (Y_i) to the corresponding frontier output (Y_i^*) using the existing technology.

$$TE_i = \frac{Y_i}{Y_i^*} \tag{5}$$

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

$$EE_i = \frac{C_i^*}{C_i} \tag{6}$$

Following Farrell (1975), the AE index was derived from equation (3.5) and (3.6) as follows:

$$AE_i = \frac{EE_i}{TE_i} \tag{7}$$

In this study TE, AE and EE estimates from SFPF were regressed using a censored Tobit model on farmer-specific explanatory variables that was explaining variation inefficiency across farmers. As the distribution of the estimated efficiencies is censored from above at the value 1, Tobit model (Tobin, 1958) is specified as:

$$E_i^* = \sum_{j=0}^{n} \beta_j X_j + V \tag{8}$$

$E_i=1$ if $E_i^* \geq 1$ and $E_i = E_i^*$ if $E_i^* < 1$

Where, E_i is an efficiency score representing TE, AE and EE; $V \sim N(0, \delta^2)$; β_j are vector parameters to be estimated; X_j represent various farmer-specific variables and E_i^* is latent variable with $E[E_i^*/X_i]$ equals $X_i\beta$.

3. Results and Discussion

3.1. Estimation of Production and Cost Functions

The maximum-likelihood (ML) estimates of the parameters of the SFPF were obtained using the STATA 11 computer program. The influence of each of the inputs used in maize production and their interaction effects are presented in Table 1. The result of the model showed that four of the input variables in the production function: land, labor, DAP and chemicals had a positive and significant effect on the level of maize production. Hence, the increase in these inputs would increase production of maize significantly as expected. As one percent increase in the size of land, amount of labor, amount of DAP and amount of chemicals would increase maize production by 0.477%, 0.144%, 0.208% and 0.19%, respectively.

The value of σ^2 for frontier of maize output was 0.073 which was significantly different from zero and significant at 1% level of significance. The significant value indicates the goodness of the specified assumption of the composite error terms distribution (Idiong, 2005; Okoye *et al.*, 2007). The estimated value of gamma was 0.728 which indicated that 72.8% 0f total variation in maize farm output was due to technical inefficiency. The returns to scale analysis coefficients were calculated to be 1.266, indicating increasing returns to scale. This implies that there was potential for maize producer to continue to expand their production because they are in the stage I of production surface, where resource use and production is believed to be inefficient. As a percent increase in all inputs proportionally would increase the total production by 1.27%. The result was in agreement with Fekadu and Bezabih (2009) who estimated the return to scale to be 1.09% in the study of TE of wheat production in Ethiopia.

Table 1. Estimation of the Cobb-Douglas frontier production function

Variables	Parameters	Coefficients	Std. Err.
Constant	β_0	1.153*	0.693
ln(land)	β_1	0.477**	0.196
ln(labor)	β_2	0.144**	0.070
ln(oxen)	β_3	0.084	0.060
ln(urea)	β_4	0.015	0.057
ln(DAP)	β_5	0.208*	0.124
ln(seed)	β_6	0.148	0.185
ln(chemicals)	β_7	0.190***	0.050
Sigma square (σ^2)		0.073***	0.017
Gamma (γ)		0.728	
Log likelihood function		39.726	

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

Inadequate farm level price data coupled with little or no input price variation across farmers of Ethiopia precludes any econometric estimation of a cost or profit frontier function. Therefore, the use of self-dual production function allows the cost frontier function to be derived and used to estimate economic efficiency in situations where producers face the same prices was given as follows:

$$lnC_{mi} = 1.669 + 0.004\omega_{1i} + 0.290\omega_{2i} + 0.080\omega_{3i} + 0.419\omega_{4i} + 0.134\omega_{5i} + 0.073\omega_{6i} + 0.023\omega_{7i} - 0.018\ln Y_i^* \quad (9)$$

Where C is per-farm costs of producing maize; Y_i^* is total maize output in Qt of the i^{th} farm adjusted for any statistical noise; ω_1 the observed seasonal rent of a hectare of land; ω_2 is the daily wage of labor; ω_3 is the daily rent of oxen; ω_4 is the price of Urea per kg; ω_5 is the price of DAP per kg; ω_6 is the price of seed per kg and ω_7 is the price index of chemicals per lit.

3.2. Efficiency Scores

The frequency distributions and summary statistics of efficiency measures for maize production were presented in Table 2. The mean TE, AE and EE of sample households were 82.93%, 66.03% and 54%, respectively, indicating that there are substantial inefficiencies in maize producers. The mean of TE indicates that, if sample households operated at full efficiency level they would increased their output by 17.07% using the existing resources and level of technology. In other words, on average the sample households decrease their inputs by 17.07% to get the output they are currently getting.

The mean score of AE result indicates that on average the sample households could increase maize output by 33.97%, if sample households used the right inputs and produced the right output relative to input costs and output price. The most allocative inefficient farmer would have an efficiency gain of 80% derived from $(1-0.20/1)^*100$ to attain the level of the most technically efficient household.

The mean EE showed that there was a significant level of inefficiency in the production process. The mean of EE (54%) indicates that maize producers could increase maize production by an average 46%, if they operated at full technical and allocative efficiency levels. The result also indicated that the farmer with average level of economic efficiency would enjoy a cost saving of about 37.26% derived from $(1-0.31620/0.504)^*100$ to attain the level of the most efficient household.

Table 2. Frequency distribution and summary statistics of maize production

Efficiency ranges	TE		AE		EE	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
00-10	0	0	0	0	0	0
11-20	0	0	1	0.80	1	0.81
21-30	0	0	0	0	1	0.81
31-40	0	0	0	0	0	0
41-50	0	0	2	1.61	18	14.52
51-60	5	4.03	34	27.42	94	75.80
61-70	16	12.91	54	43.55	10	8.06
71-80	15	12.10	21	16.94	0	0
81-90	55	44.35	8	6.45	0	0
91-100	33	26.61	4	3.23	0	0
Maximum		97		100		66
Minimum		57		20		19
Mean		82.93		66.03		54
Std. Deviation		0.1008		0.1072		0.0598

3.3. Determinants of Efficiency in Maize Production

The 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 Tobit regression model.

The results of censored Tobit model are presented in Table 3. AGE has a positive and significant impact on TE and EE. Thus, the variable indexes experience and serve as a proxy for human capital showing that farmers with great farming experience will be better management skills and have an interest in the use of new methods of production. The resut is similar to the finding of Arega and Rashid (2005), Khai *et al*. (2008), Dawang *et al*. (2011) and Gbigbi (2011).

Table 3. Determinants of efficiency in maize production among sample households

Variables	TE		AE		EE	
	ME	Std. Error	ME	Std. Error	ME	Std. Error
Constant	0.6136***	0.0597	0.4930***	0.0685	0.3823***	0.0346
AGE	0.0017**	0.0008	0.0005	0.0009	0.0010**	0.0005
EDUCH	-0.0004	0.0026	0.0092***	0.0030	0.0014	0.0015
HHSZE	0.0050	0.0037	-0.0039	0.0043	-0.0004	0.0022
SEX	-0.0560***	0.0225	0.0038	0.0258	0.0183	0.0130
OFNFA	0.0390**	0.0180	0.0014	0.0208	0.0182*	0.0105
TCULTLND	-0.0013	0.0079	-0.0062	0.0091	0.0056	0.0046
LNDOWNR	0.0510**	0.0251	-0.0213	0.0289	0.0419***	0.0145
CRDTU	0.0102	0.0169	0.0031	0.0194	0.0249***	0.0098
FEXTVST	-0.0007	0.0008	0.0018*	0.0009	-0.0001	0.0005
TRAING	0.0254	0.0219	-0.0343	0.0252	-0.0013	0.0127
LNDFRAG	-0.0120	0.0127	0.0113	0.0146	0.0018	0.0074
SLOPE	-0.0183	0.0145	0.0178	0.0166	-0.0072	0.0084
PROXTY	0.0005	0.0007	-0.0007	0.0009	-0.0006	0.0004
PAGRPOLY	0.0861***	0.0327	0.0971***	0.0374	0.0523***	0.0188
PENVHZRD	-0.0283	0.0199	-0.0200	0.0228	0.0060	0.0115
LIVSTK	0.0013	0.0014	0.0027*	0.0016	0.0012	0.0008
LOG L	127.2956		106.5855		192.0726	

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

The estimation coefficient of education was consistently positive though had significant impact on AE. The result indicates that, AE require better knowledge and managerial skill than TE and EE. In other words, educated households have relatively better capacity for optimal allocation of inputs. In line with this study, research done by Ogundari and Ojo (2007) and Keinde and Awoyemi (2009) have also found education to impact on AE positively and significantly.

Sex of household head was found to have negative and significant impact on TE which implicated that female household headed were responsible for many household domestic activities[1] and use inputs fewer than male household heads. The result is consistent with Isah *et al.* (2013).

The coefficient of off/non-farm activities[2] have positive and significant impact on TE due to the income obtained from such activities could be used for the purchase agricultural inputs and augments financing of household expenditures which would entirely dependent on agriculture. This income availability shifts cash constraint outward and enables households to make timely purchase of those inputs which they cannot provide from on farm income. The result is in line with Arega and Rashid (2005) and Hassen (2011).

The land arrangement or land ownership had positive and significant impact on TE and EE. Households who used their own land for maize production have relatively better level of TE and EE. This implies that, farmers who produce on their own land use inputs properly and give priority during farming periods than who manage sharecropped land. The result is in agreement with (Fekadu and Bezabih, 2009).

Credit utilized had positive and significant impact on EE which suggests that, on average households with credit utilized tend to exhibit higher levels of efficiency. Credit utilized permits a household to enhance efficiency by removing money constraints which may affect their ability to apply inputs, implements and farm management decisions on time. The finding is consistent by Hasan (2006) and Gbigbi (2011).

Frequency extension visit was the number of times that the households contact with extension agents.

[1] Household domestic activities are collecting of fire wood from field, fetching water from the far distance rivers, child rearing and household management obligation.

[2] Off/non-farm activities are both off-farm and non-farm activities. Non-farm activities are activities which are not related to farm activities such as petty trade, handcraft, local beer trade, rent from asset, grain milling non-farm labor, etc and off-farm activities are activities which are related to farm activities such as sale of annual and perennial crops, livestock and livestock products, farm labor, etc.

The coefficient of extension visit had positive and significant impact on AE. The result showed that farmer households who received regular extension visits by extension workers appear to be more allocative efficient than counterparts. The result is consistent with Obare *et al*. (2010) and Gbigbi *et al*. (2011) who indicated that regular contact with extension workers facilitates practical use of modern techniques, adoption of improved agricultural production practices and use inputs appropriate way.

Households were asked about their perception with regards to the existing agricultural policies[1] they have befitted from government support programs. The result showed that the variable had positive and significant impact on TE, AE and EE. This implied that households who feel benefits from agricultural policies under taken by the government. The result is consistent with Khai and Yabe (2011) who found significant positive relationship between agricultural policy and efficiency.

The coefficient for livestock holding (LTU) was positive and significant impact on AE which confirms the considerable contribution[2] of livestock in maize production system. The result is in line with (Solomon, 2012).

4. Conclusions and Recommendations

This study was conducted to estimate technical, allocative and economic efficiencies and identify factors affecting efficiency among maize producer households in Bako Tibe district, Oromia National Regional State, Ethiopia. There are a number of studies that have dealt with technical efficiency of farmers in developing countries. However, there is only few studies that analyzed technical, allocative and economic efficiencies altogether which this study is dealing with.

The result confirmed the efficiency of maize production provided opportunity to enhance the level of technical, allocative and economic efficiencies of maize producer households. The stochastic frontier production function and self-dual cost function indicates that the average TE, AE and EE value of the sample households was 82.93%, 66.03% and 54%, respectively. These results indicates that households can increase maize production by 17.07% without increasing inputs if they were technically efficient, reduce current cost of inputs by 33.97% with cost minimization way and increase maize production by 46% if they operated at full technical and allocative efficiency levels.

To help different stakeholders to enhance the current level of efficiency in maize production, factors affecting the level of efficiency were identified. Accordingly, the Tobit regression model revealed that age of household head, off/non-farm activities, land ownership, perceived favorable agricultural policy had positive and significant impact while sex of household heads had negative and significant impact on TE as expected. AE, ability to use least cost combination of inputs to produce a given output was affected by education level, frequency of extension visit, perceived favorable agricultural policy and livestock holding had positive and significant impact on as expected. Finally, age of household head, off/non-farm activities, land ownership, credit utilized and positive perceived favorable agricultural policy had positive and significant impact on EE as expected.

A policy maker's interest may lie both on knowing how far a given farm can increase its output without using further resources and also identification of important policy variables for action. This study revealed that maize production involves substantial inefficiency among the maize producer households. Economic inefficiency in maize production is dominated by allocative inefficiency, suggesting that improvements in allocative efficiency represent a greater opportunity for enhancing maize production than technical efficiency. Therefore, the existing level of inefficiency in maize production is high and this calls for better attention of policy and researchers in tackling the sources of these inefficiencies to improve the welfare of maize producing farmers.

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[1] Agricultural policies are like as pricing, marketing, natural resource conservation and one to five team formation in the country.

[2] Contribution of livestock in maize production in the study area was source of draft power, food, incomes used for inputs purchased and organic fertilizers.

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