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PRODUCTION EFFICIENCY OF MAJOR CROPS AMONG SMALLHOLDER FARMERS IN CENTRAL ETHIOPIA

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Abstract. This study was carried out with the aim of analyzing the technical, allocative and economic efficiencies of smallholder farmers in the production of major crops and their determinants in central Ethiopia. Multistage sampling technique was used to collect primary data from 386 sampled households through a semi structured questionnaire. Data Envelopment Analysis (DEA) and Tobit regression model were employed for analysis and the mean technical, allocative and economic efficiencies were 0.48, 0.59 and 0.29 respectively. Age, access to credit, training, and farming information; livestock size, marital status, level of education, farming experience, cooperative membership, off/non-farm income have influenced the efficiencies of smallholders significantly.

Keywords: efficiency, DEA, crop production, multi input-output, smallholders, Central Ethiopia

INTRODUCTION

The agriculture sector in Ethiopia accounted for about 33.3% of GDP and 76% of export share (NBE, 2019). The sector employs about 85% of the labour force and is dependent on smallholder's production. According to CSA (2018) report, cereals, pulses and oil seeds constitute 81%, 12.5%, and 6.5% respectively from the total area covered by grains. Five major cereals (*teff*, wheat, maize, sorghum, and barley) occupy about 75% of total area of cultivated land in Ethiopia (PARM, 2016). Production of cereals contributed to 87.48% of which maize, *teff*, wheat and sorghum made up 27.43%, 17.26%, 15.17%, and 16.89% respectively (CSA, 2018). Their production is entirely dependent on rain with only 3 percent of irrigated production for food crops and about 37% of all vegetable production of the country is irrigated (FAO/IFC, 2015).

Agriculture yields in Ethiopia are exceptionally low by international standards and overall production is highly susceptible to weather shocks, particularly droughts (Alemayehu et al., 2011). Several factors contribute for the low production of smallholders including lower utilization of modern technologies. Agricultural production is entirely nature dependent and the recurrent rainfall variability results in significant production variations. The main motive of smallholders' production is fulfilling their subsistence requirements. It is believed that limited input availability and precarious environmental conditions determine the production decisions of smallholders. Smallholders' resource utilization is generally considered to be very poor. The production efficiency may vary from farmer to farmer because of various factors. Analyzing resource use efficiency is a basis for implementing agricultural policy which helps in improving smallholders' productivity (Tchale, 2009). Few research activities undertaken on efficiency analysis in the central highlands of Ethiopia were identified (Nega and Ehui, 2006; Mussa et al., 2012; Wudineh and Endrias, 2017) and they were mostly focused on the efficiencies of single enterprise. Hence, this research was conducted on the multi-input multi-output production efficiencies and it identifies the determinants of technical,

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allocative and economic efficiencies of smallholders in the study area.

LITERATURE REVIEW

Efficiency of a firm consists of two parts: technical and allocative. Allocative efficiency measures a firm's success in choosing an optimal set of inputs and technical efficiency measures the success in producing maximum output from a given set of inputs (Farrell, 1957). The technical efficiency of an individual producing unit is defined in terms of the ratio of the observed output of the corresponding frontier output, given the available technology (Ajibefun, 2008). Farrell (1957) explained the production efficiency clearly using a production function with two inputs in Fig. 1 below.

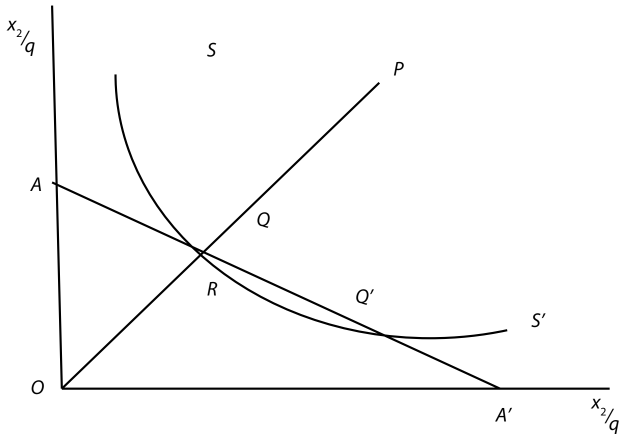

Fig. 1. Farrell's technical and allocative efficiency
Source: Farrell, 1957.

The technical efficiency (TE) of a firm is most commonly measured by the ratio

$$TE = \frac{OQ}{OP}$$

It can be seen from Fig 1. that *OR*/*OQ*, the price or allocative efficiency of P, depends on the slope of AA', the slope of SS' at Q, and its curvature between Q and Q'. Economic efficiency is the combination of technical efficiency and allocative efficiency. It is calculated as the product of allocative efficiency and technical efficiency.

$$EE = TE \cdot AE$$

Stochastic frontier analysis (SFA) and data envelopment analysis (DEA) are the two mostly used efficiency measurement techniques and the limitations of the SFA are addressed in the DEA which is non parametric models (Paul et al., 2017). The study requires application of multi input-multi output model. The SFA usually used to estimate efficiencies of multi-input- single-output and fails to calculate the efficiencies of smallholders. The commonly used approach in evaluating performance of a set of decision-making units (DMUs) which convert multiple inputs to outputs is Data envelopment analysis (Cvetkoska, 2011; Fang and Li, 2015). It is non-parametric approach used as an alternative to SFA for information extraction from population observations of decision processes to estimate the production frontier that does not require specification of production function (Brazdik, 2004). DEA requires neither the specification of the production or cost function or the distributional assumptions, which can create specification errors (Fang and Li, 2015). The model involves the use of linear programming method to construct a non-parametric piece wise surface (frontier) over the data (Coelli et al., 2005).

Empirical studies on efficiencies were carried out by various researchers. Dipeolu et al. (2008) have used data from pepper growers using multistage sampling procedure in southwest Nigeria to analyze the efficiency using stochastic frontier analysis, revealing that there is a room for the average farmer to increase pepper output or save costs using existing technology. The study conducted for reallocating decision-making units using revenue efficiency across a set of decision-making units (DMUs) under a centralized decision-making environment shows the possibility of achieving higher total revenue compared with that of the conventional non-centralized revenue efficiency model (Fang and Li, 2015). A study conducted to examine the technical and scale efficiencies in Ambara state, Nigeria (Okeke et al., 2012) for sample of irrigated and rain fed farmers using DEA shows irrigated farmers are resource efficient as compared to rain fed and recommended to increase the level of education of farmers with extension service to be familiar with new technologies. DEA technique was used to determine the resource use production efficiency of *teff*, wheat and chickpea in central highlands of Ethiopia conducted by Mussa et al. (2012). The result shows eliminating resource use inefficiency could improve about 30% of the minimum annual income of average farm households. To analyze the effect of demographic, socioeconomic, farm attributes, marketing, institutional variables on efficiencies, a two-limit Tobit model procedure was used by Sisay et al. (2015) in southwestern part of Ethiopia. The Tobit model result shows family size, number of years in formal education, livestock size, farming experience, cooperative membership and ownership of mobile phone have positive significant influence on efficiencies while farm size has negative significant influence on technical, allocative and economic efficiencies.

METHODOLOGY

Description of the study area

This research was based on data collected from smallholder farmers in Oromia regional state Oromia Special Zone surrounding Addis Ababa, Ethiopia. The Special Zone was selected as part of central highlands of Ethiopia. The special zone has a total area of 4,800 km^2 and the zone is categorized into six districts (BoFED, 2011). The population size of the zone was estimated at 829,532 with 151 peasant associations (BoFED, 2014). Major crops produced in the zone are cereals, pulses, oilseeds, vegetables and the dominant cereals produced are *teff*, barley and wheat.

Sampling design and techniques

Multi-stage random sampling techniques were employed in sample selection process in purposively selected Oromia Special Zone (OSZ). Three districts out of total six were selected randomly. The study districts were Akaki, Sebeta and Sululta. From the total kebeles in the three districts, three kebeles from Akaki and Sululta and four kebeles from Sebeta district were selected proportionally. Simple random sampling techniques were employed to select a total of 386 representative samples proportionally from each Kebeles. The total sample size was determined based on the sample selection for large population (Cochran, 1963) as shown in equation:

$$n_o = \frac{z^2pq}{e^2} = \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2} = 386 \qquad (1)$$

Where: n_0 is the sample size, z^2 is the abscissa of the normal curve that cuts off an area α at the tails (1-α equals the desired confidence level, e.g., 95%), e is the desired level of precision, p is the estimated proportion of an attribute that is present in the population, and q is 1-p. The value for z is found in statistical tables which contain the area under the normal curve.

Table 1 presents distribution of the selection number of households across districts and kebeles.

Table 1. Sampled districts, population and sample size

District	Name of kebele	No of HHs	Sampled HHs	Sample proportions (%)
Akaki	GelanArabsa	672	47	12.2
	Gerado/Gemeda	340	25	6.5
	OdaNebe	390	28	7.3
Sebeta	Awash Beldho	360	34	8.8
	GejaQoye	439	40	10.4
	GejaMigira	340	32	8.3
	GejaGedamba	401	39	10.1
Sululta	ChancoBuba	832	67	17.4
	Derba	436	34	8.8
	MuloAdadi	497	40	10.4

Source: Zonal, District and Kebele agricultural office and own computation.

The numbers of smallholder farmers in the kebeles were chosen randomly based on the information obtained from agricultural development offices.

Sources of data and collection methods

For this study both primary and secondary data were used. Primary data was collected from smallholders through a semi structured questionnaire using face to face interview. Secondary data obtained was from district, kebeles, and OSZ documents, mainly population and classifications of the administrative units which were used for choosing sampled respondents. For primary data collection, enumerators were employed based on their educational backgrounds and those who have attained at least their high school studies. Training was given to familiarize with the survey questionnaire to gather information required from smallholders.

Methods of data analyses and model specification

Cross sectional data collected from sampled households was analyzed using mathematical and econometric methods. Mathematical programming technique selected was Data Envelopment Analysis (DEA) using linear programming technique. DEA measures the relative efficiency of decision-making units (Saen, 2010). The model specified by Sherman and Zhu (2006) as shown in equation (2). Maximize the efficiency rating θ *for* decision making unit o:

$$\text{Maximize}\,\theta = \frac{u_1 y_{1o} + u_2 y_{2o} + ... + u_r y_{ro}}{v_1 x_{10} + v_2 x_{20} + ... + v_m x_{mo}} = \frac{\sum_{i=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$

Subject to:

$$SU_j = \frac{u_1 y_{2j} + u_2 y_{2j} + ... + u_r y_{rj}}{v_1 x_{2j} + v_2 x_{2j} + ... + v_m x_{mj}} = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1 \quad (2)$$

$u_1, \ldots, u_2 > 0$ and $v_1, \ldots, v_m \geq 0$

where:

- j – number of decision-making units (DU) being compared in the DEA analysis
- SU_j – decision making unit number j
- θ – efficiency rating of the decision-making unit being evaluated by DEA
- y_{rj} – amount of output r used by decision making unit j
- x_{ij} – amount of input i used by decision making unit j
- i – number of inputs used by DMUs
- r – number of outputs generated by the DMUs
- u_r – coefficient or weight assigned by DEA to output r
- v_i – coefficient or weight assigned by DEA to input i.

Data required in applying DEA is the actual observed outputs produced y_{rj} and the actual inputs used x_{ij}, during one time period for each decision-making unit in the set of units being evaluated. If the value of θ for the decision-making unit being evaluated is less than 100%, then that unit is inefficient, and there is the potential for that unit to produce the same level of outputs with fewer inputs (Sherman and Zhu, 2006). The value of θ obtained was the efficiency score for the i^{th} decision-making unit (DMU). The value $\theta = 1$ implies a point on the frontier hence a technically efficient DMU.

Table 2. Description and measurement of production and production inputs

Variables	Definitions
Output variables	
Wheat	Wheat outputs produced (kg)
Barley	Barley outputs produced (kg)
Teff	Teff outputs produced (kg)
Maize	Maize output produced (kg)
Bean	Bean output produced (kg)
Chickpea	Chickpea output produced (kg)
Lentil	Lentil output produced (kg)
Grass pea (vetch)	Grass pea (vetch) output produced (kg)
Input variables	
Land	Cultivated land for each crop in hectares
Labour	Family and hired labour in man-days for each crop
Fertilizer	Amount of chemical fertilizer in kg for each crop
Seed	Quantity of seed in kg for each crop
Costs variables	
Land rent	Retail price of land used for crop production (birr per hectare)
Wage	Wage rate of labor for farming (birr per day)
Cost of fertilizer	Average price of fertilizer (birr per kg)
Cost of seed	Average price of seed for each crop (birr per kg)

Source: own elaboration.

Specification of Tobit model for identifying efficiency factors

The estimated efficiency scores were used to determine the factors affecting efficiencies of crop production using Tobit regression model. Efficiency scores lie between 0 and 1; usually several values at 1 but often none at or close to zero (McDonald, 2009). Two limit

Tobit model is used at stage 2, the unobservable latent or underlying regression by Greene (2012) is given by equation (3):

$$y_i^* = x_i\beta + \varepsilon_i \quad (3)$$

where: $\varepsilon_i \setminus x_i$ – are normally, identically and independently distributed with mean zero and variance σ^2, x_i – is a 1 by K vector of observations on the constant and k-1 efficiency factors (explanatory variables) and β a k X 1 vector of unknown coefficients.

$$y_i^* = \begin{cases} y_i^*, \text{if } 0 < y_i^* < 1 \\ 0, \text{ if } y_i^* \le 0 \\ 1, \text{ if } y_i^* \ge 1 \end{cases} \quad (4)$$

The data generating process (DGP) postulates that the observed efficiency scores y_i are the censored values of y_i^*, with censoring below zero and above one (McDonald, 2009) as indicated in equation (4).

Table 3. Summary of efficiency variables and working hypothesis

Efficiency variables	Measurement	Expected sign
Age of the household head	Continuous	+
Sex of the household head	Dummy (1 = male, 0 = female)	–
Marital status	Dummy (1 = married, 0 = otherwise)	–
Family size	Discrete	+
Education level of household head	Continuous	+
Farming experience	Continues	+
Access to credit	Dummy (1 = yes, 0 = no	+
Cooperative membership	Dummy (1 = yes, 0 = no)	+
Access to information	Dummy (1 = yes, 0 = no)	+
Access to training	Dummy (1 = yes, 0 = no)	+
Livestock size in TLU	Continuous	–
Off/non-farm income	Dummy (1 = yes, 0 = no)	+

Source: own elaboration.

RESULTS AND DISCUSSION

Demographic and socio-economic variables

The summary statistics in table 4 shows the mean values of descriptive variables, the deviations from mean and the value ranges. Smallholder farmers involved in the study are male headed and accounted for 93% of participants. The average age was about 47 years with a maximum of 90 years and a minimum of 24, indicating most of them are still in the active age group. The average family size was estimated 5.88 higher than the national average of 4.8, regional average and persons in rural areas of 5.2 (CSA, 2017).

From sampled farmers, 22% of respondents have access to credit to their farm, 53% are members of cooperative associations mainly they mention as general agricultural cooperatives expecting to obtain farm inputs through the association. From the respondents, 97% and 92% have access to farming information and training respectively, 46% of smallholders are involved in off-farm employment to generate additional income. The wealth status of smallholders measured by livestock size estimated as 8.61 TLU which ranges from minimum 0 to 43.25 TLU.

Table 4. Summary of determinant factors

Efficiency variables	Mean	Std. dev.	Min	Max
Age of the household head	46.76	11.58	24	90
Sex of the household head	0.93	0.26	0	1
Marital status	0.91	0.29	0	1
Education level of household head	3.24	3.83	0	12
Family size	5.88	2.50	1	24
Farming experience	25.62	12.07	3	70
Access to credit	0.22	0.42	0	1
Cooperative membership	0.53	0.50	0	1
Access to information	0.97	0.18	0	1
Access to training	0.92	0.28	0	1
Livestock size in TLU	8.61	5.10	0	43.25
Off/non-farm income	0.46	0.50	0	1

Source: own computation based on survey results, 2018/2019.

Table 5. Production and production inputs of major crops

Crop item	Production (Qt)	Land (ha)	Seed (kg)	Labour (man/day)	Fertilizer (kg)
Wheat	16.12	0.89	118.58	60.44	192.68
Barley	12.11	0.27	98.88	18.30	152.77
Teff	10.33	0.72	27.50	53.78	173.52
Maize	8.90	0.03	6.53	1.94	40.71
Bean	4.49	0.11	44.37	6.77	48.13
Lentil	5.82	0.21	52.22	9.88	75.00
Chick pea	8.11	0.28	37.03	7.37	50.00
Grass pea (vetch)	4.54	0.08	37.86	5.15	–

Source: survey results, 2018/2019.

Production and production inputs

The amount of crops produced in the study area was presented in Table 5. The average land allotted for production of major crops on average is estimated at about 2.6 hectares. The total (average) production and required inputs for land allotted for production of each crop (Table 5). The costs of inputs were calculated based on estimated values of inputs with their unit prices.

Efficiency scores of smallholders using Data Envelopment Analysis (DEA)

The results of efficiency scores show the mean technical, allocative and economic efficiencies are 0.48, 0.59 and 0.29 respectively. This implies that if resources are utilized efficiently, smallholders can increase their agricultural production by 52%, and reduce cost of production by 41% and total cost by 71%. The frequency of efficiency scores was presented in Table 6.

Table 6. Frequency distribution of DEA efficiency scores

Efficiency range	TE		AE		EE	
	freq.	%	freq.	%	freq.	%
0.000–0.199	25	6.5	10	2.6	132	34.32
0.200–0.299	52	13.51	18	4.68	110	28.58
0.300–0.399	73	18.97	26	6.76	76	19.76
0.400–0.499	79	20.53	50	13	35	9.10
0.500–0.599	59	15.34	101	26.22	13	3.38
0.600–0.699	37	9.61	80	20.79	3	0.78
0.700–0.799	26	6.76	64	16.62	7	1.82
0.800–0.899	9	2.34	21	5.46	0	0
0.900–0.999	2	0.52	7	1.82	1	0.26
1	24	6.22	9	2.33	9	2.33
Mean	0.48		0.59		0.29	
	386	100	386	100	386	100

Source: own computation based on survey results, 2018/2019.

The distributions of technical efficiency show 59.33% of smallholders have the relative technical efficiencies between 0 and 0.5, and 34.46% of them have relative technical efficiency between 0.5 and 0.99 (Table 6). About 27% of smallholders have relative allocative efficiencies less than 0.5. About 94% of smallholders have relative technical efficiencies less than 0.9 and 40.49% of smallholders have relative technical efficiencies greater than 0.5.

Determinants of efficiency

The efficiency scores obtained from the Data Envelopment Analysis (DEA) were used as a dependent variable which has indexes between 0 and 1. Tobit regression model was used to regress these indexes against the socioeconomic, demographic, and institutional variables that are expected to affect the technical, allocative and economic efficiencies of sampled households.

Tobit regression model result

The Tobit regression model result presented in Table 6 indicated efficiency of smallholder farmers are determined by various factors positively or negatively. Marital status, level of education, farming experience, access to credit, cooperative membership, access to farming information, and off/non-farm employment has positive influence on the technical, allocative and economic efficiencies while age of the household head, access to training and livestock size has negative relations to efficiencies.

Age of the household head: As shown in the Table 7, age has negative significant impact on allocative and economic efficiencies at 5% and 10% level of significance respectively. The marginal effect of age shows that as the age of the household head increases by one year, allocative and economic efficiencies are reduced by 0.4% and 0.3% respectively. It is against the research outputs of (Kifle et al., 2017) but consistent with the research output of Hassen (2016) where older farmers are inefficient as compared with their young counterparts.

Marital status of household head: As expected it has a positive influence on allocative and economic efficiencies of smallholder farmers at 5% level of significance. The marginal effect of marital status shows that as compared to unmarried and divorced household heads, allocative and economic efficiencies are improved by 8% and 6.2% respectively. The result is against the expectations and the study result of Coker et al. (2018) which has negative influence on efficiencies. This may be due to sharing of ideas among the spouse in the production activity which leads to be more efficient.

Educational level of the household head: As expected education, has a positive influence on the technical and economic efficiencies of smallholder farmers. It affects technical and economic efficiencies at 1% level of significance as compared with farmers with low level of education, farmers with higher level of education understand the importance of using new technologies, developing information gathering habits, when and what type of seed and other inputs to use. Farmers at higher level of education are better in utilizing new technology. The marginal effect shows, as the level of education of household head increases by 1 year, technical and economic efficiencies improve by 1.2% and 0.8% respectively. The study result was supported by research output of Mburu et al. (2014) in the analysis of economic efficiency and farm size in Kenya, Adugna et al. (2019) on the study of technical, allocative and economic efficiencies of small-scale sesame farmers in west Gonder and the research outputs of Shumet (2011), Beyan et al. (2013), Chepngetich et al. (2013), and Hassen (2016).

Farming experience: It has a positive influence on technical efficiency at 5%, allocative and economic efficiency at 1% level of significance. The positive influence is the result of farm households' skills they have developed in their lifetime. They know practical problems related to their production, the remedial measures they used which they have learned throughout their life. The marginal effect of farming experience indicates that as the farming experience increases by one year, technical, allocative and economic efficiency of households improves by 0.4%. The research output of Gbigbi (2011) supports the positive influence of farm experience on economic efficiencies.

Access to credit: It has positive impact on technical, allocative and economic efficiency of smallholders at 5% level of significance. Based on the values of marginal effect, technical, allocative and economic efficiencies will increase by 6.2%, 4.8%, and 5.2% respectively as compared to farmers who have no access to credit. Credit facilitates productions for smallholder farmers in terms of purchase of farm tools and inputs or obtaining improved livestock breads. The result was supported by the research outputs of Gbigbi (2011), Shumet (2011), and Kifle et al. (2017).

Table 7. Regression results of technical, allocative and economic efficiencies

Variable	TE		AE		EE	
	coef. (std. err.)	dy/dx (std. err.)	Coef. (std. err.)	dy/dx (std. err.)	coef. (std. err.)	dy/dx (std. err.)
Constant	0.372*** (0.097)		0.563*** (0.074)		0.220*** (0.077)	
Age	–0.003 (0.002)	–0.003 (0.002)	–0.004** (0.001)	–0.004** (0.001)	–0.003* (0.002)	–0.003* (0.002)
Sex	0.002 (0.054)	0.002 (0.054)	0.012 (0.042)	0.012 (0.042)	0.008 (0.043)	0.008 (0.043)
Marital status	0.045 (0.048)	0.045 (0.048)	0.080** (0.037)	0.080** (0.037)	0.062* (0.038)	0.062* (0.038)
Level of education	0.012*** (0.003)	0.012*** (0.003)	0.002 (0.002)	0.002 (0.003)	0.008*** (0.003)	0.008*** (0.003)
Farming experience	0.004** (0.002)	0.004** (0.002)	0.004*** (0.001)	0.004*** (0.001)	0.004*** (0.001)	0.004*** (0.001)
Family size	–0.004 (0.005)	–0.004 (0.005)	0.002 (0.004)	0.002 (0.004)	–0.002 (0.004)	–0.002 (0.004)
Access to credit	0.062** (0.028)	0.062** (0.028)	0.048** (0.022)	0.048** (0.022)	0.052** (0.022)	0.052** (0.022)
Cooperative member	–0.023 (0.025)	–0.023 (0.025)	0.056*** (0.019)	0.056*** (0.019)	0.007 (0.020)	0.007 (0.020)
Access to information	0.144** (0.070)	0.144** (0.070)	0.076 (0.054)	0.076 (0.054)	0.134** (0.055)	0.134** (0.055)
Access to training	–0.131*** (0.047)	–0.131*** (0.047)	–0.088** (0.036)	–0.088** (0.036)	–0.135*** (0.037)	–0.135*** (0.037)
Livestock size	0.003 (0.002)	0.003 (0.002)	–0.006*** (0.002)	–0.006*** (0.002)	–0.002 (0.002)	–0.002 (0.002)
Off/non-farm employ	0.044* (0.023)	0.044* (0.023)	–0.002 (0.018)	–0.002 (0.018)	0.015 (0.019)	0.015 (0.019)
LR $chi^2(12)$	36.43***		54.65***		42.33***	
Pseudo R^2	0.8441		–0.3029		–0.2586	
Log likelihood	–3.363		117.531		103.005	
Linear prediction		0.489		0.588		0.288

Marginal effects computed for significant variables and the value in the cell explain $\frac{\partial[(Zy)-(Z_L),Zy]}{\partial x_j}$ (change in probability).
*, **, *** Significant at $p < 0.1$, $p < 0.05$, $p < 0.01$ respectively.
Source: survey results, 2018/2019.

Cooperative membership: As expected it has positively affecting allocative efficiencies at 1% level of significance. Farmers who are members of cooperatives can obtain viable information and production facilities and inputs easily through their association to facilitate their production. The marginal effect of cooperative membership indicates that as compared with farmers who are not members, cooperative members are allocatively efficient with 5.6%. The research findings of Sibiko et al. (2013) and Adugna et al. (2019) support the positive impact of cooperatives on efficiencies of smallholders.

Access to farming information: It has positive influence on the allocative and economic efficiency at 5% level of significance. As compared with farmers who do not have access to farm information, accessible farmers have a possibility to increases technical and economic efficiency in their agricultural production by 14.4% and 13.4% respectively. Nowadays farming information is one of the particularly important resources to the farming community. Access to information is a requisite to realize economic benefits through new methods (Mulwa et al., 2017). To obtain farm services, to protect their crop from disease outbreak, rain, and other factors which affects the production activity; availability of farming information is unquestionable. As expected, it has positive relations with efficiencies of smallholders. The result was supported by the research outputs of Tadie et al. (2019) in their study of technical efficiency in red pepper production in north Gondar zone.

Access to training: It has negative influence on technical, allocative and economic efficiencies at 1%, 5% and, 1% level of significance respectively. The marginal effects of access to training shows, as compared with farmers who have no access to training, the technical, allocative and economic efficiencies of trained farmers are reduced by 13.1%, 8.8%, and 13.5% respectively. The results are against the expectations of the hypothesis and the research findings of Mburu et al. (2014). This show there is more emphasis need to be given for training in the study area which improves the efficiencies of smallholders' production. The smallholders responded that the trainings they have participated were focused on soil and water conservation practices, new technology, and marketing. However, the result shows that they understood that a lot was required in technology that capacitates smallholders to increase their efficiency.

Livestock size: It has affected allocative efficiency negatively at 1% level of significance. As size of livestock increases, the production efficiencies of smallholders decrease. Those who have better wealth can perform their production activity less as compared with those with limited wealth. Smallholders are spending more on their livestock keeping hence less for their crop management activity due to shortage of forage and grazing land for livestock. The marginal effects show, as the livestock size increases by 1 TLU, the allocative efficiency of farmer is reduced by 0.6%. The negative impact of TLU on technical efficiency is supported by the research outputs of Shumet (2011) and Mussa et al. (2012).

Off/non-farm employment: It has positive influence on technical efficiency at 10% level of significance. The technical efficiency of the farmer involved in off/non-farm employment increases. Several reasons may be mentioned for this to happen. As a farmer involved in off-farm activity, he has gained additional information from outside environment that directly eases his production activity. The income gained from off/non-farm employment allows him to purchase the required farm inputs easily as compared with those who don't have access to additional income. The marginal effect of off-farm employment shows, as compared with a farmer who is not involved in off/non-farm employment, the technical efficiency increases by 3.9%. Some of the mentioned studies that show positive impacts of off farm employment on efficiencies are the ones by Jema (2007), Kifle et al. (2017), and Adugna et al. (2019).

CONCLUSIONS

This study was initiated to provide information on crop production efficiency of smallholders producing wheat, barley, *teff*, bean, lentil, chickpea, and *grass pea* (vetch). The technical, allocative and economic efficiency results were 0.48, 0.59 and 0.29 respectively which tells us that resources are not utilized efficiently and there is a possibility of increasing the outputs by 52%, and reducing cost of production by 41%, hence total costs are reduced by 71%. The Tobit model result, used to identify the determinants of efficiency, indicates that the level of education has positive influence on the technical efficiency of smallholder farmers. Level of education, access to credit, access to training, and livestock size are identified variables that have positive influence on efficiencies of smallholder farmers. Access to farm information influences technical and economic efficiencies negatively by reducing the probability of allocative and economic efficiencies.

The efficiency of smallholders shows that the resources are underutilized. Hence trainings and supply of agricultural inputs including credit access to purchase required inputs need to be strengthened. The study result shows that credit facilitates production of smallholder farmers and their efficiencies. Credit facilities need to be expanded to address the needs of farmers. Farmers who are members of cooperatives have easily obtained viable information, production facilities and inputs through the association, which positively affected efficiencies.

The government puts due emphasis on strengthening the cooperatives to address the services to non members too.

The trainings have negative impact on efficiencies of smallholders. Type of training determines efficiencies of smallholders. Trainings on use of new technologies expected to improve the efficiencies and time of trainings should be given at the slack periods of production. The negative influence of livestock ownership on technical efficiency is believed to result from spending more on livestock and keeping it at the expense of crop management. Emphasizing strengthening relations of livestock and crop production to improve production of one against the other is recommended.

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